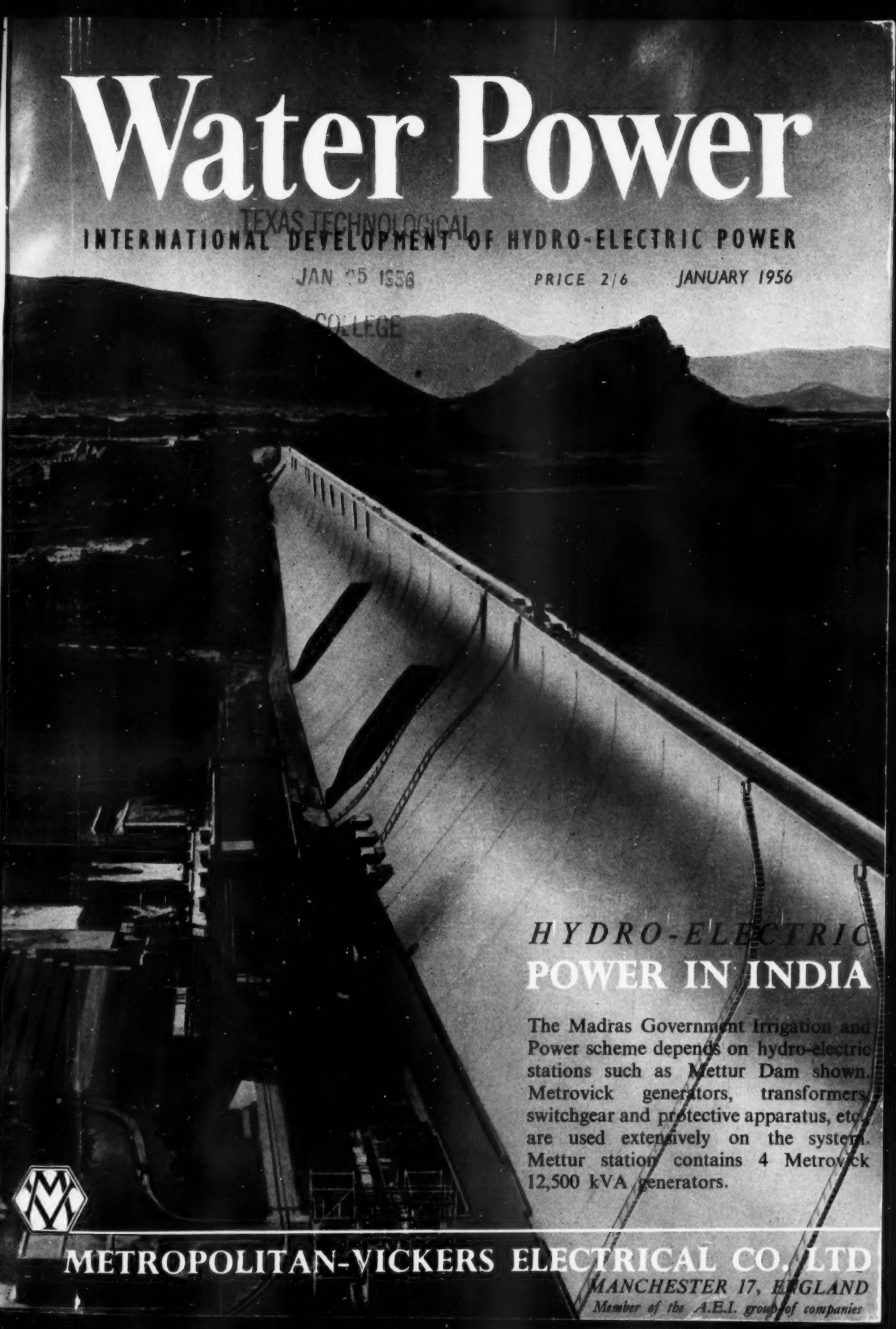
Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

TEXAS TECHNOLOGICAL
JAN 25 1956
COLLEGE

PRICE 2/6 JANUARY 1956

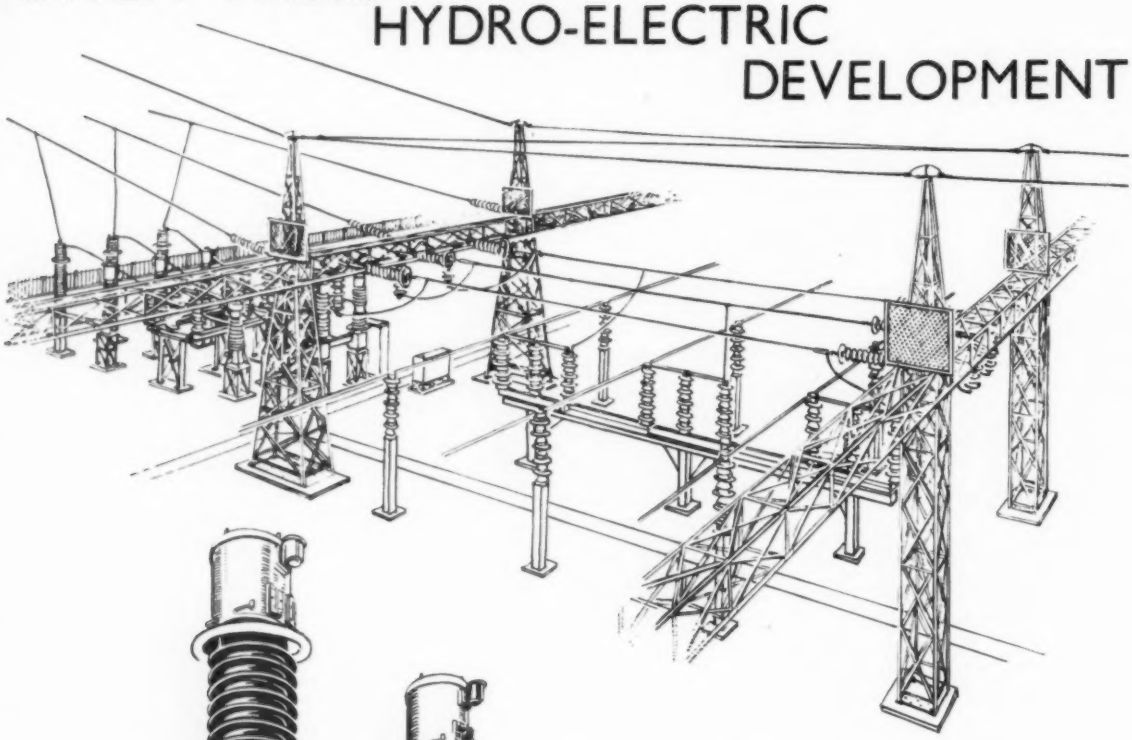


HYDRO-ELECTRIC
POWER IN INDIA

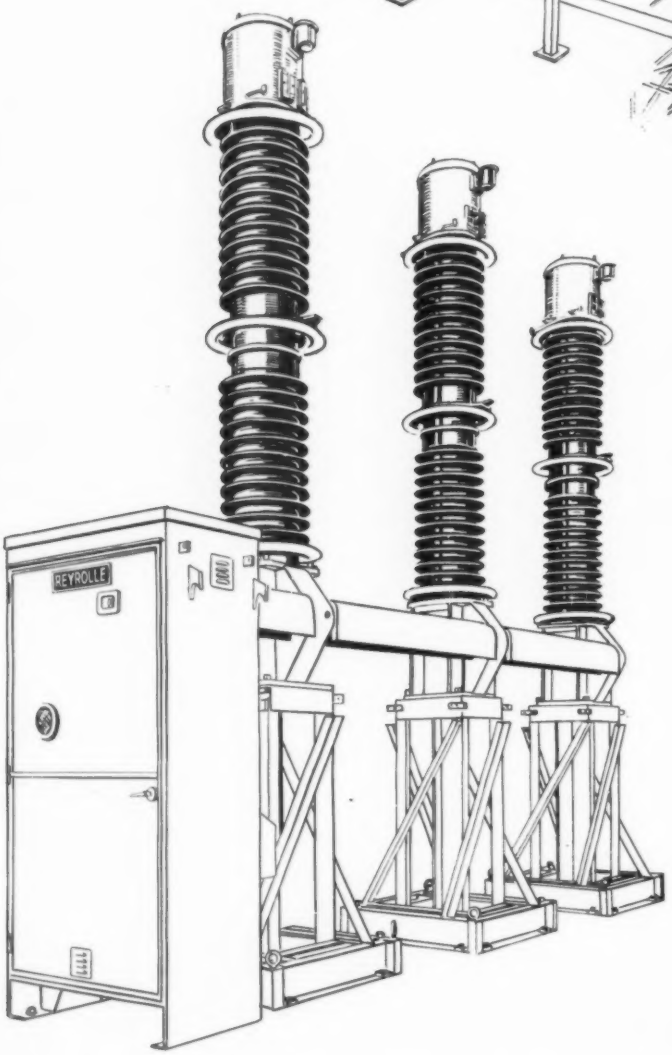
The Madras Government Irrigation and Power scheme depends on hydro-electric stations such as Mettur Dam shown. Metrovick generators, transformers, switchgear and protective apparatus, etc., are used extensively on the system. Mettur station contains 4 Metrovick 12,500 kVA generators.

METROPOLITAN-VICKERS ELECTRICAL CO. LTD
MANCHESTER 17, ENGLAND
Member of the A.E.I. group of companies

OWEN FALLS HYDRO-ELECTRIC DEVELOPMENT



Owen Falls 132-kV Switchyard



132-kV 2500 MVA
small-oil-volume
switchgear, having a
730-kV impulse-voltage
withstand, was
selected for OWEN FALLS,
KAMPALA NORTH, and TORORO
switching-stations
on the equator
to meet conditions of
high altitude (4000') and
frequent lightning storms

Reyrolle

A. REYROLLE & COMPANY LIMITED · HEBBURN · CO. DURHAM

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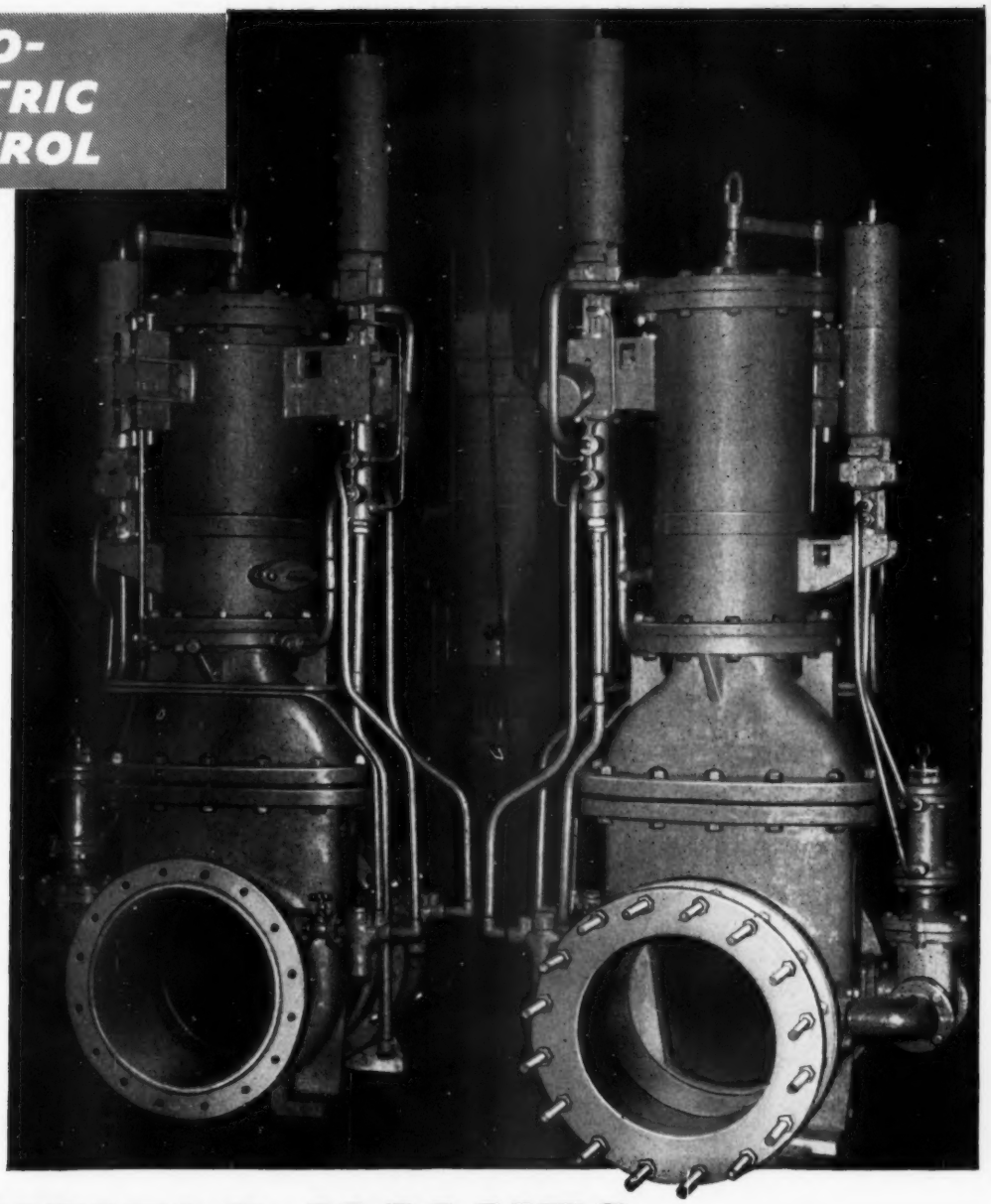
HYDRO-ELECTRIC CONTROL



GLENFIELD VALVES

in the Power House

Innumerable Glenfield valves are effecting control at turbine inlets, in all parts of the world.

The illustration shews two 20in. dia. hydraulically operated Sluice Valves supplied for turbine inlet control on a hydro-electric scheme in Scotland. They are constructed of Meehanite—high grade cast iron—with gunmetal cylinder liner and seatings, and forged bronze spindle and tail rod. Each is designed to operate against a full unbalanced head of 372 ft. and has parallel faces in the body and on door, and a slip joint on the downstream flange. They can be closed in emergency by push button control through solenoid operated pilot valves.

Glenfield

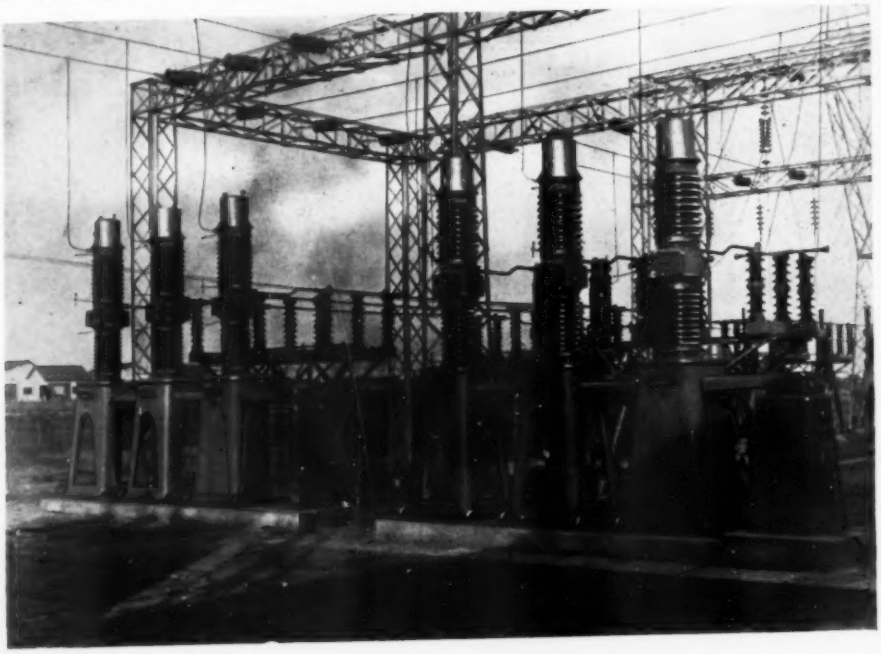
GLENFIELD & KENNEDY, LIMITED, KILMARNOCK

Head Office & Works: KILMARNOCK, SCOTLAND

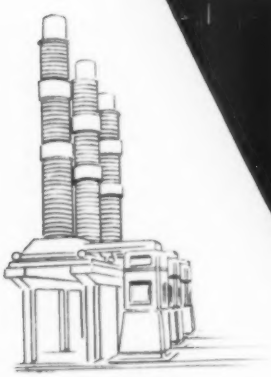
SCARPA & MAGNANO

Società per Azioni - Cap. Versato L. 200.000.000

SAVONA - MILANO

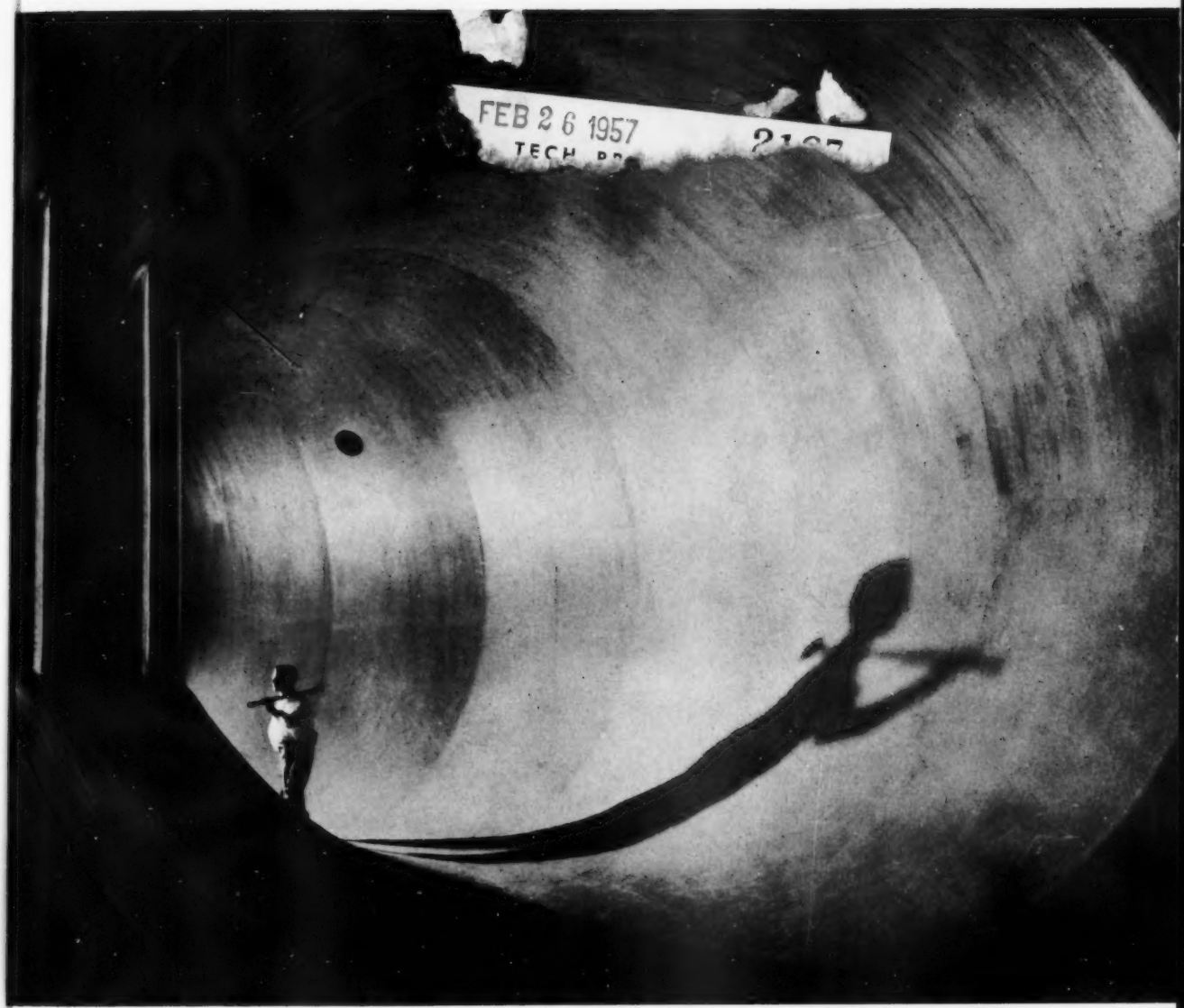


Type PO/91 P Circuit-breakers and 80 kV disconnecting switches installed at the Campana S. Nicolas substation of Messrs. D.A.y E.E., Buenos Aires. This substation is wholly equipped with Scarpa & Magnano made switchgear.



Electrical switchgear for middle and high voltages, from 1 up to 220 kV indoor and outdoor installation

Works : SAVONA, V. Fiume 2 - Ph. 20159 - 20741 - 21230 • Cml. Management : MILAN, V. A. Manzoni 12 -Ph. 708251



Inside the spiral casing of the first Kaplan turbine at OWEN FALLS. This casing has an inlet diameter of 21 ft. The turbines, of which there will be ten ultimately, each develop 22,500 BHP at 62 ft. nett head.

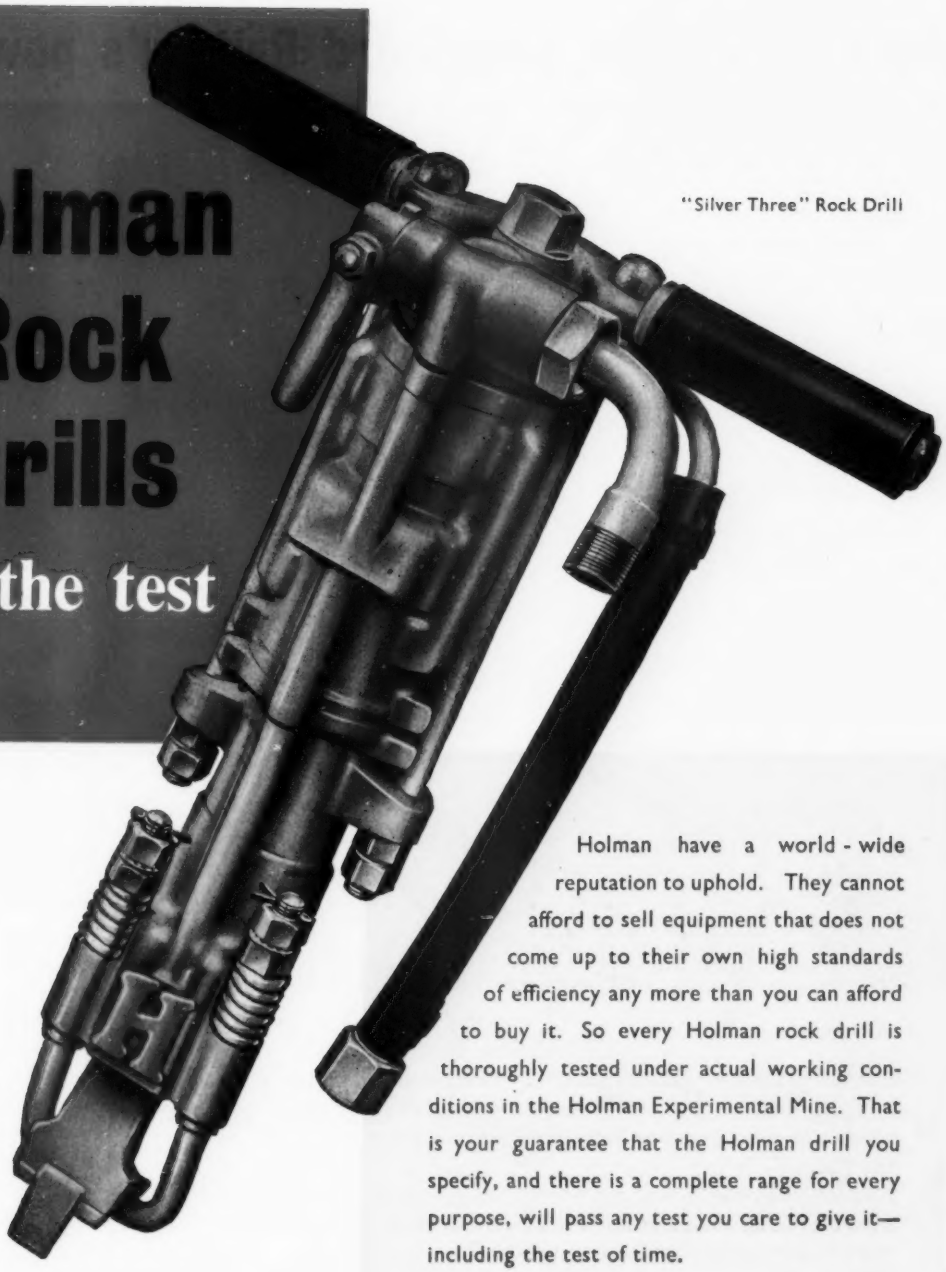
Boving

& COMPANY LIMITED
56, KINGSWAY, LONDON, W.C.2.

LONDON : AUSTRALIA : NEW ZEALAND : INDIA : PAKISTAN

3,500,000 H.P.
is the enormous output of the 4,800 hydraulic Turbines which have been manufactured since the foundation of J. M. Voith, St. Poelten, 50 years ago.
Here are some details of our production programme:
2 Francis helical turbines, each 56,000 h.p.
3 Francis helical turbines, each 48,000 h.p.
4 double Pelton turbines, each 35,800 h.p.
3 Francis helical turbines, each 33,200 h.p.
4 Pump storage stations, each 32,000 h.p.
4 Francis helical turbines, each 21,000 h.p.
2 Francis helical turbines, each 16,000 h.p.
2 Pelton turbines, each 5,700 h.p.
Workshop assembly of a Francis spiral turbine for an output of 32,000 h.p.; head: 144 m. (480 ft.); speed: 375 r.p.m.
4 complete sets of this turbine and pump combination are being manufactured for the pumped-storage station at Niederwartha, Dresden.
TU 577
J. M. VOITH St. Poelten Austria

Holman Rock Drills stand the test



"Silver Three" Rock Drill

Holman have a world-wide reputation to uphold. They cannot afford to sell equipment that does not come up to their own high standards of efficiency any more than you can afford to buy it. So every Holman rock drill is thoroughly tested under actual working conditions in the Holman Experimental Mine. That is your guarantee that the Holman drill you specify, and there is a complete range for every purpose, will pass any test you care to give it—including the test of time.

ROCK DRILLS
AIR COMPRESSORS
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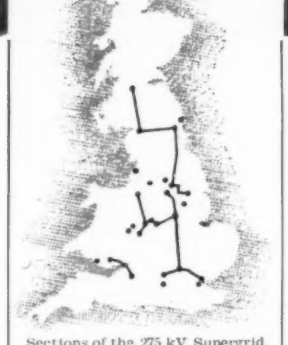
More than 550,000 "ARMOURLIGHT" Toughened Glass Insulators are being supplied for the Central Electricity Authority's 275 kV Supergrid which will carry power to Britain's vital industries, from the Clyde to the Thames.

These toughened glass insulators have proved themselves specially suitable for high voltages for public power supplies; and their electrical and mechanical strength means trouble-free operation.

They cannot be punctured by lightning surges and they have a high resistance to power arcs. A damaged unit can be detected by quick visual inspection from the ground, thus saving time and trouble and eliminating the need for line testing.

Leading electricity authorities throughout the world are using ever-increasing quantities of "ARMOURLIGHT" toughened glass insulators.



Sections of the 275 kV Supergrid for which "Armourlight" Toughened Glass Insulators are being supplied.

For technical advice and literature, write to Pilkington Brothers Limited, Insulator Sales Department, Ravenhead Works, St. Helens, Lancs.

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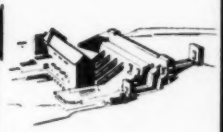
Thermal and Hydroelectric Power Stations, Substations, Transformer and Convertor Stations, Switching Stations, Control Rooms, Overhead Lines and Underground Cable Systems, Turbo-sets, Steam Turbines, Generators, Transformers, Reactors, Rectifiers and Inverters, Capacitors, High-voltage and Low-voltage Switchgear, Relays, Automatic and Remote Control Equipment, Regulating Equipment, System and Machine Protection Equipment.



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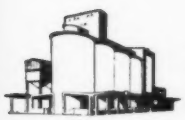
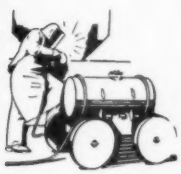
Electrical Equipment of Mines, Smelting Works, Rolling Mills, Chemical Works, Manufacturing and Refining Works. Special Drives, Control, Switching and Regulating Equipments for all types of Industrial Works. Electrical Equipment for Cranes, Lifts and other Hoists. Welding Sets, Medium- and High-frequency equipment for industrial purposes, Infrared Equipment, Ultraviolet Radiation Equipment.





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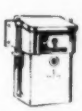

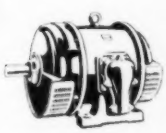

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Small Appliances, Space Heating Equipment, Water Heaters, Vaccum Cleaners, Fans, Hand Driers, Laundry Driers, Rotary Ironers, Refrigerators.

232 E

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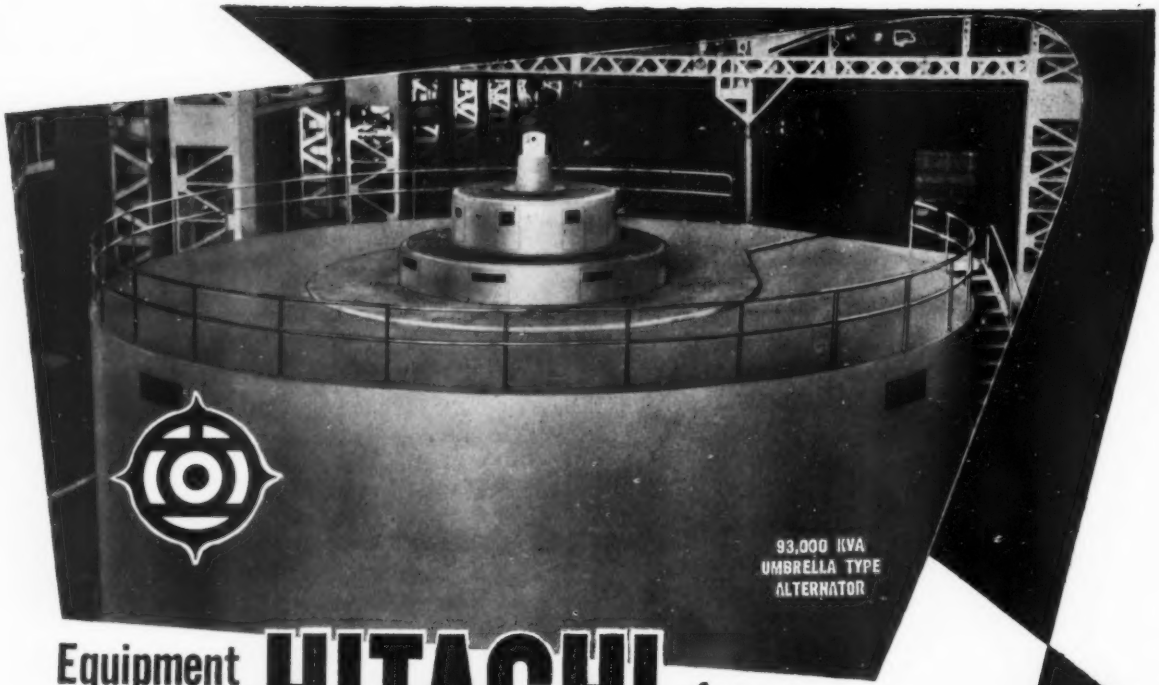

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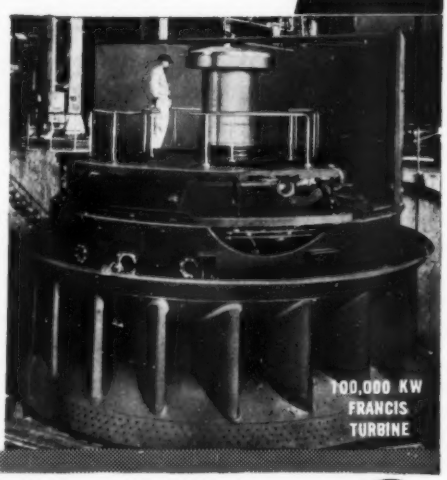

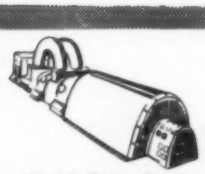
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Indispensable in modern power stations

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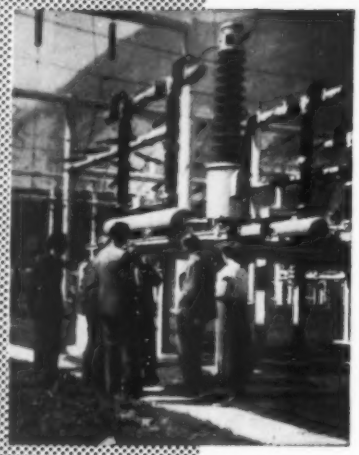
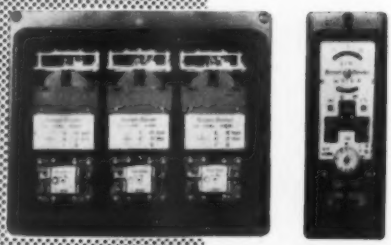


Brown Boveri air-blast circuit-breakers are built from proved, standard components for voltages up to 400 kV and breaking capacities up to 20000 MVA; they ensure stable system operation and protect your installations, machines and apparatus

Brown Boveri quick-acting regulators for the regulation of a.c. and d.c. voltage, current, power, frequency and pressure, require little space and power, no upkeep, only one single setting, and function rapidly and reliably



Brown Boveri generator protection equipment detects widely differing types of faults without risk of undesired tripping and safeguards your generators against disturbances of all kinds

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Brown Boveri telephony and remote supervisory control facilitates supervision and control of your stations. It can be readily adapted to the specified conditions and is economical and ready for service at any time

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We have been continually producing hydraulic turbine equipment and accessories for the past 93 years. With this background of accumulated experience, we are prepared to give your specification or inquiries accurate and prompt attention, submitting technical and specific proposal data covering turbine equipment called for.

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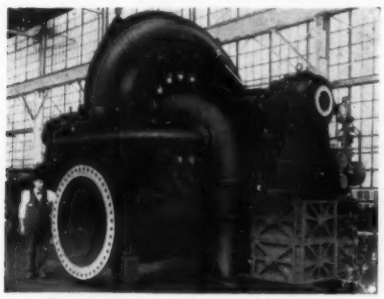

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We specialize in the design and manufacture of vertical and horizontal hydraulic turbine equipment in a wide range of capacities and types. Within this range we design and build turbines of specific speeds from the lowest practical for Francis runners to the highest practical for runners of the propeller type—all applicable according to their specific speeds to a range of heads up to approximately 1,000 feet.

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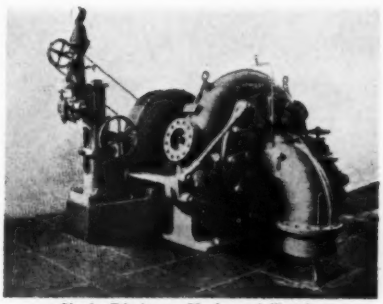
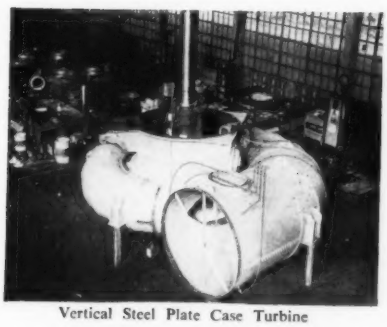
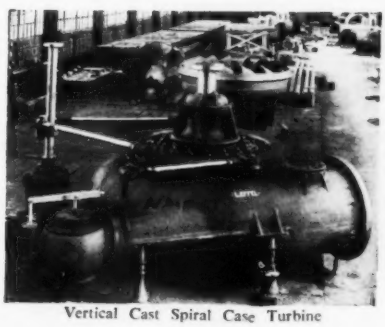


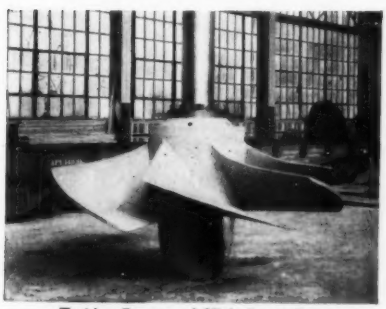
Single Discharge Horizontal Turbine



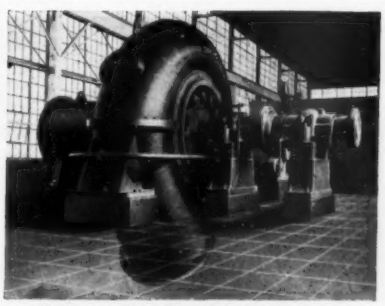
Vertical Steel Plate Case Turbine



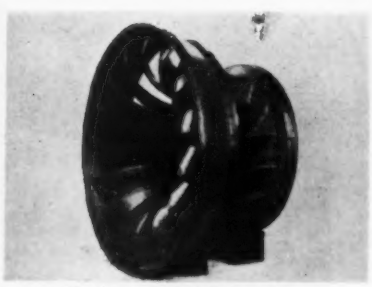
Vertical Cast Spiral Case Turbine



Turbine Runner of High Speed Type



Horizontal Steel Plate Spiral Case Turbine



Turbine runner of Francis Type

THE JAMES LEFFEL & CO.

DEPARTMENT W **SPRINGFIELD, OHIO, U.S.A.**

MORE EFFICIENT HYDRAULIC POWER FOR 93 YEARS

Test runner used for Ets Neyrpic's study of n° 3 turbine constructed for the Kemano Power Station by Dominion Engineering Company

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MAY WE OFFER OUR
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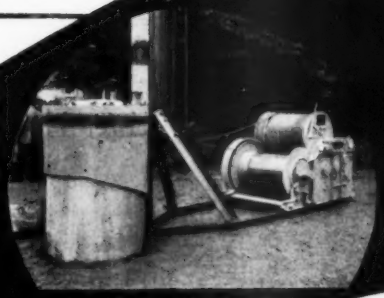


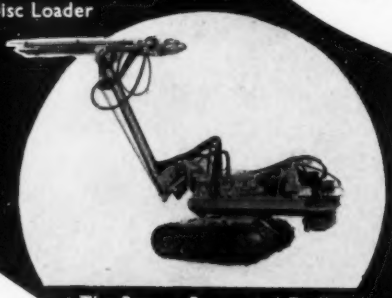
The Annular Core Drill

SMG
SALZGITTER

The Bunker Train

ROCK DRILLING
AND
LOADING EQUIPMENT
for
Tunnelling
and
Headway Driving

The Rotary Disc Loader



The Rotary-Percussive Drill

The Rocker Shovel

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High Pressure

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a lot of care
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DORTMUNDER UNION BRÜCKENBAU-AG · PLANTS AT DORTMUND AND GELSENKIRCHEN
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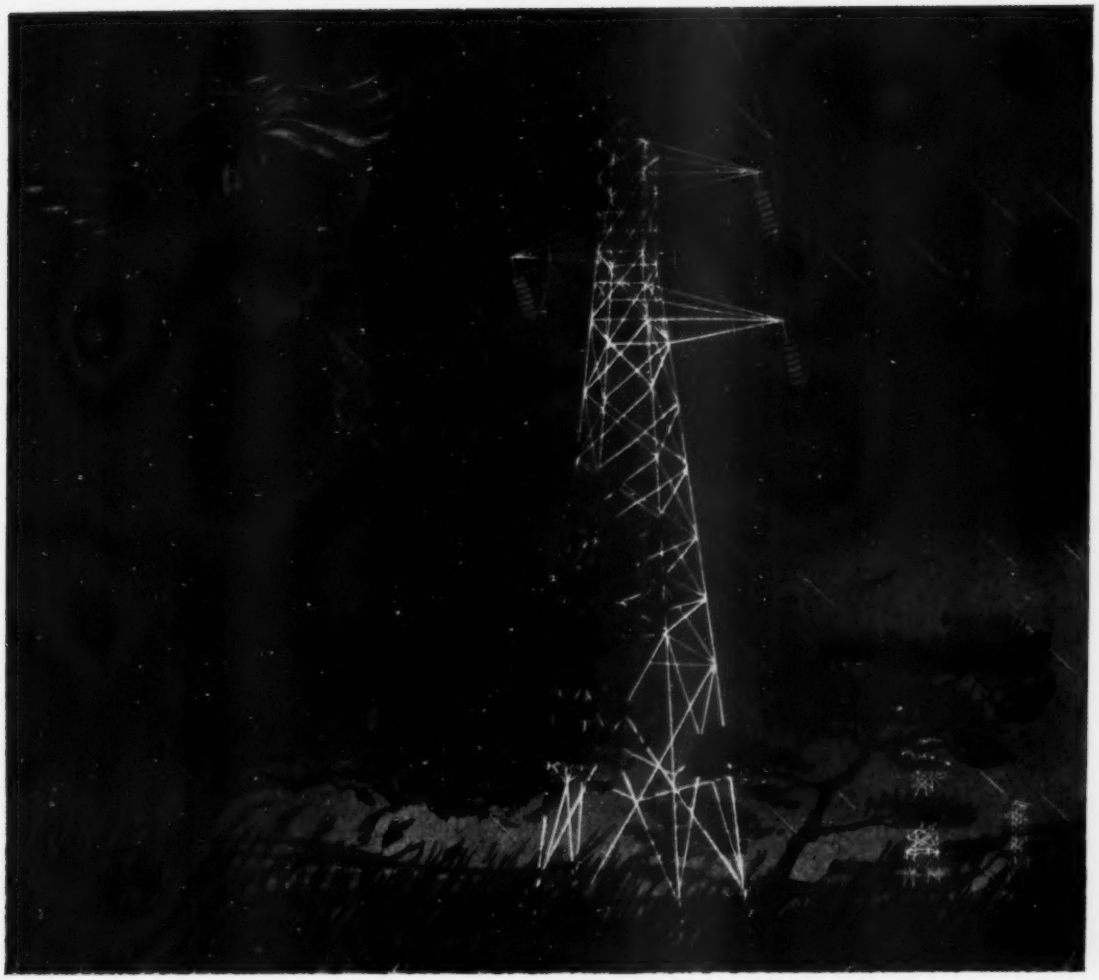
The Painter's View



Blow, blow, thou winter wind

THE howling gale that tears the leaves from the bough will rage harmlessly against the transmission tower built by Painter Brothers—because our designers and engineers are specialists.

Because we have always been Tower Specialists and have developed our own fabrication methods which ensure accuracy and interchangeability; because we have had nearly thirty years' experience of hot dip galvanizing, and because we have our own Tower Testing Station to prove the behaviour of structures under every sort of loading condition, Painter Brothers' towers are Towers of Strength.

Painter Bros. Ltd.

HEREFORD

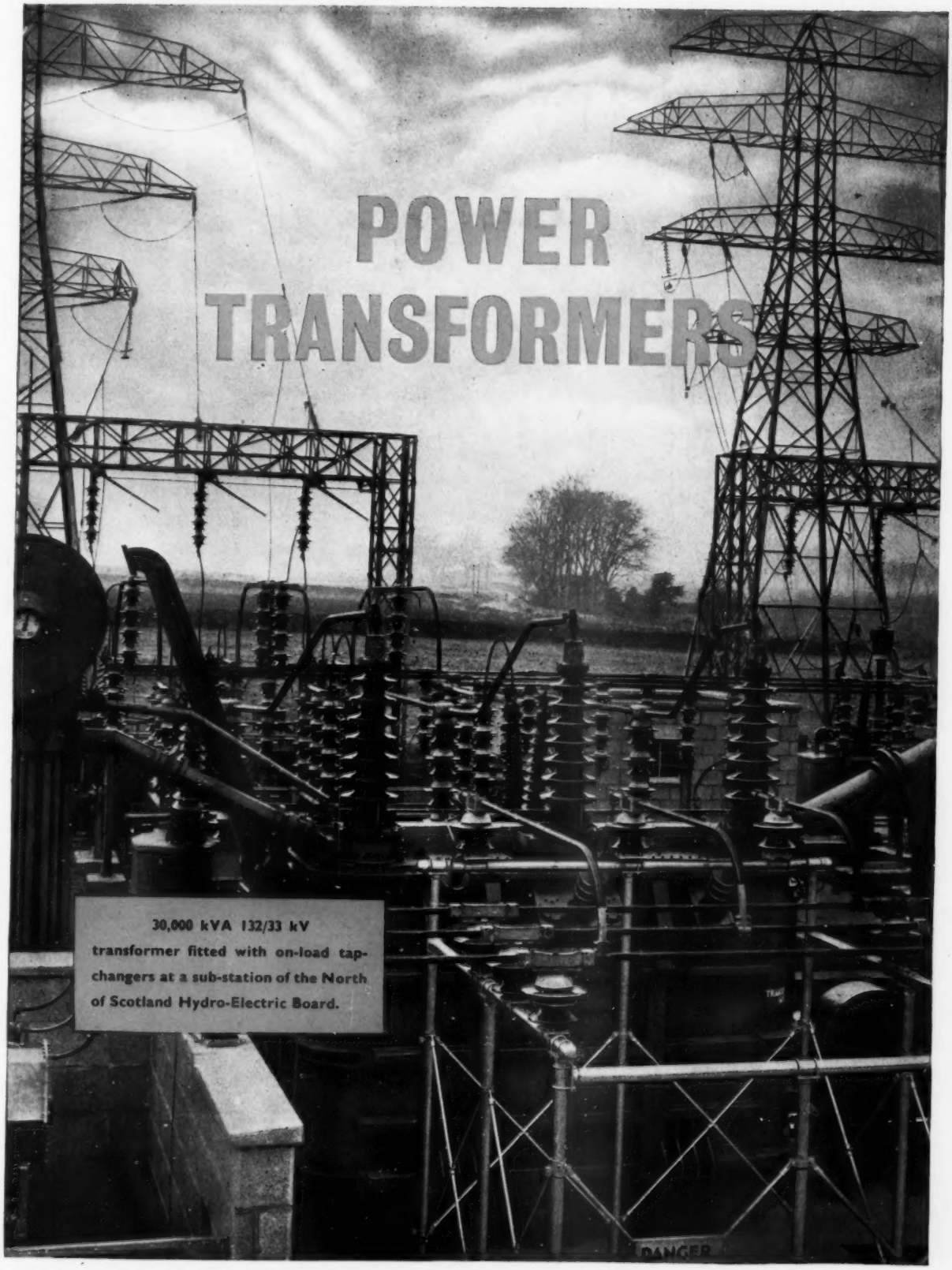
Overhead Electrical Transmission Towers and Poles; Radio Masts; Callender-Hamilton Bridges.

speeding dam construction in India

In India, where weather rules working time, hold-ups due to inefficient or inferior equipment can seriously hamper a construction programme. That is why so many projects in India, such as the Madupatty Dam pictured here, depend on Henderson Cableways for continuous handling of building materials. Low cost materials handling is the key to successful Civil Engineering in any part of the world—and wherever there is a Dam or Barrage, a Bridge or Viaduct to be built. Henderson Cableways will usually be the most practical means of construction.

Henderson

JOHN M HENDERSON & CO LTD KING'S WORKS ABERDEEN



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FRANCO TOSI S.p.a ★ LEGNANO (ITALY)

HYDRAULIC TURBINES

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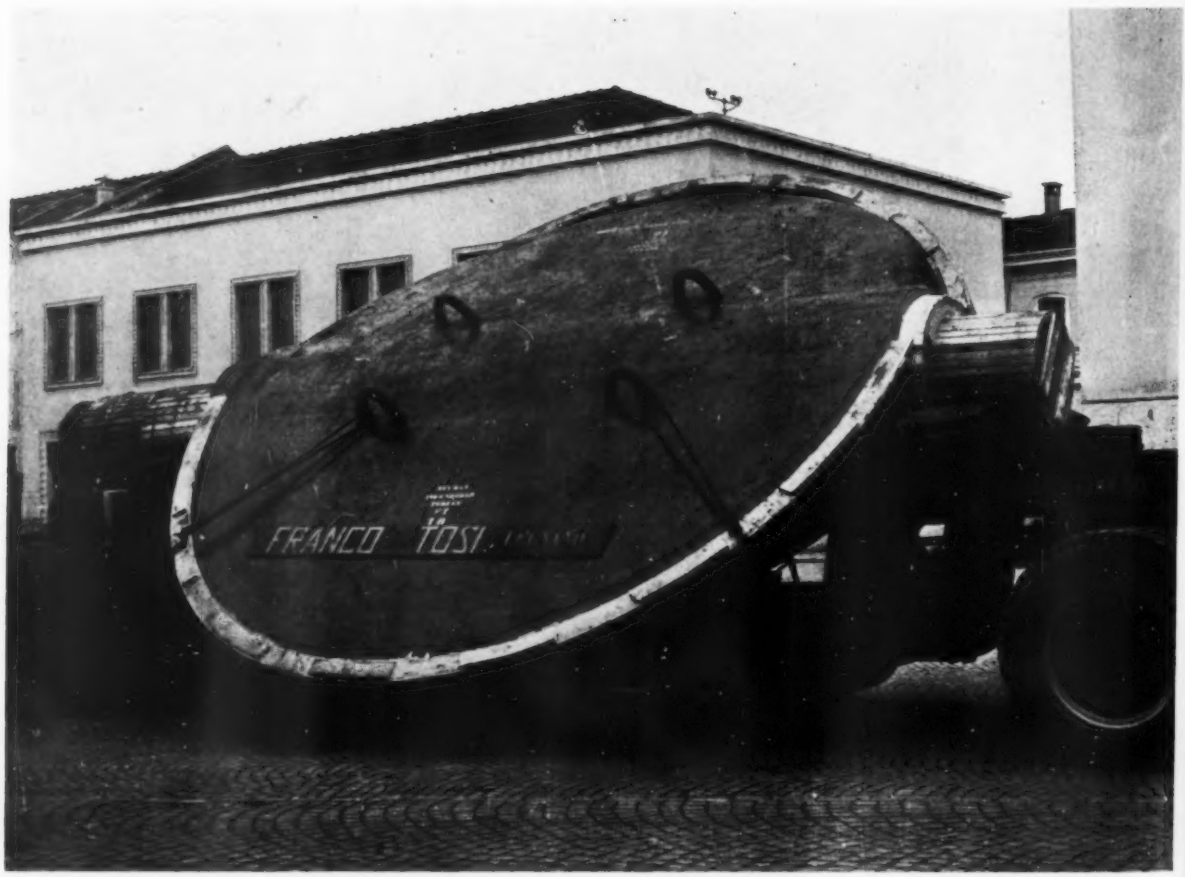

SEYHAN WATER PROJECT (TURKEY)

Butterfly Valve Leaf, 5,020m. Diameter—Weight 50 Tons

to vikings in volcanic Iceland

Descendants of the old Norsemen, who a thousand years ago settled in Reykjavik, are now using power from the new 46·5 MW underground hydro-electric power plant at the River Sog, 32 miles away. Danish civil engineers were entrusted with this, the first tunnel project in Iceland, which comprised among other things a tailrace tunnel 2,100 feet long. Co-operating with Swedish experts the plant was successfully completed within three years.

CIVIL ENGINEERS & CONTRACTORS

E. PIHL & SØN

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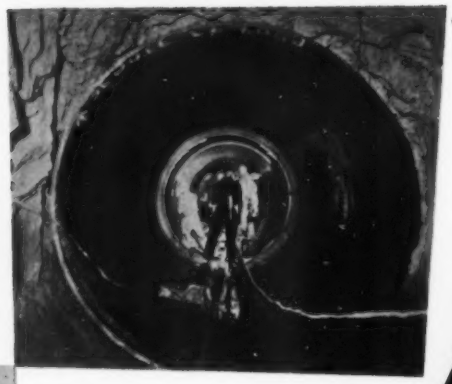
HEAD OFFICE: URANIAVEJ 12, COPENHAGEN, DENMARK. TEL.: PIHLSON — BRANCH OFFICE: FOSSKRAFT, REYKJAVIK, ICELAND. TEL.: FOSSKRAFT



utstanding achievements by

VRB In the Construction of Moder Penstocks

VRB penstock designs incorporate th fruits of the latest metallurgic research, based on exhaustive tes

VRB employ a large number of specia ised workers and can therefo effect rapid completion of a project

VRB welders are approved specialists high-pressure pipeline work

VRB test every welded seam by X-r or ultra-sonic methods, accordi to requirements

VRB penstocks are made exclusively high-tensile easily weldable steel having a yield point of 65,500 lb. p sq. in. and a minimum elongation 20 per cent, thus ensuring maximu economy of materials and a hig degree of safety

VRB are known the world over for the high quality workmanship

Call in

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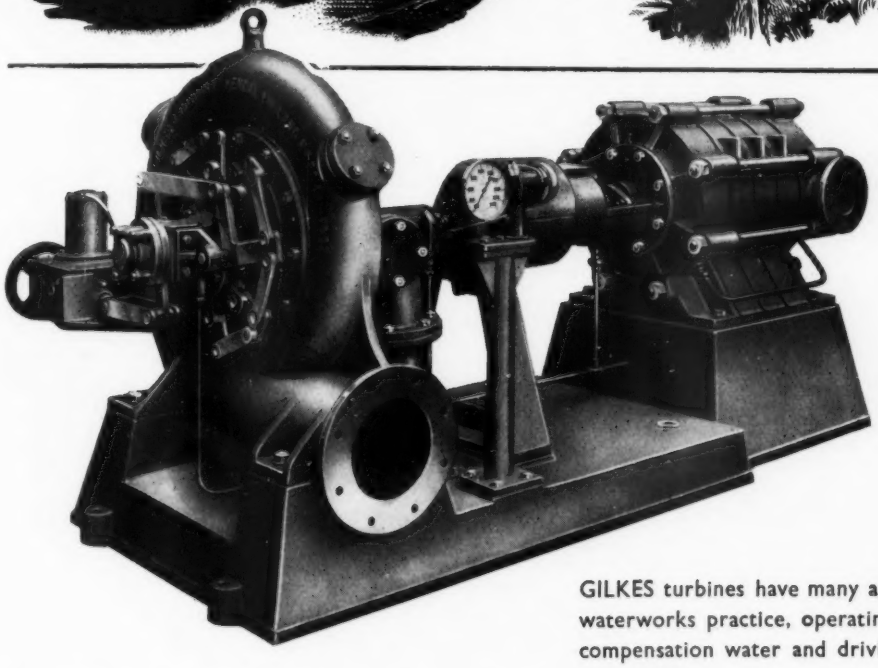

Two GILKES Francis Turbine-Pump Units raise filtered water to high level reservoirs and three GILKES Turgo Impulse Wheels generate all the power that is required in the Hoy Filtration Station of the Caithness County Council's Loch Calder Water Supply Scheme.

GILKES turbines have many applications in modern waterworks practice, operating on raw, filtered or compensation water and driving pumps or electric generators.

GILKES

Turbines & Pumps for Water Supply Schemes

GILBERT GILKES & GORDON LTD

WATER TURBINE & PUMP MANUFACTURERS

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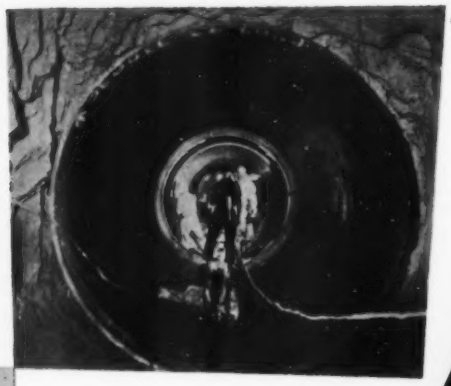

utstanding achievements by

VRB In the Construction of Modern Penstocks

VRB penstock designs incorporate the fruits of the latest metallurgical research, based on exhaustive tests

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VRB penstocks are made exclusively of high-tensile easily weldable steels, having a yield point of 65,500 lb. per sq. in. and a minimum elongation of 20 per cent, thus ensuring maximum economy of materials and a high degree of safety

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Call in

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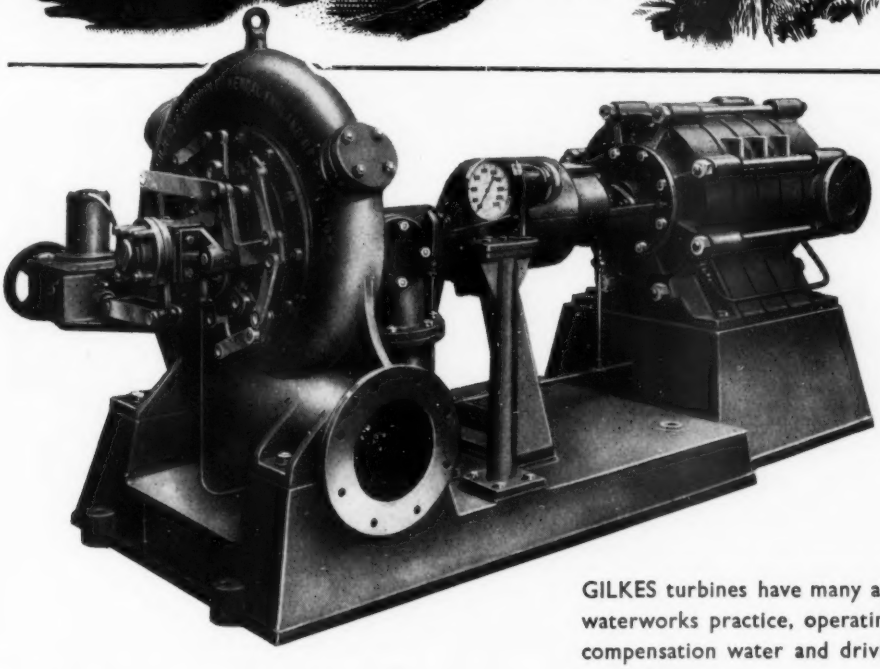
GERMANY

VRB



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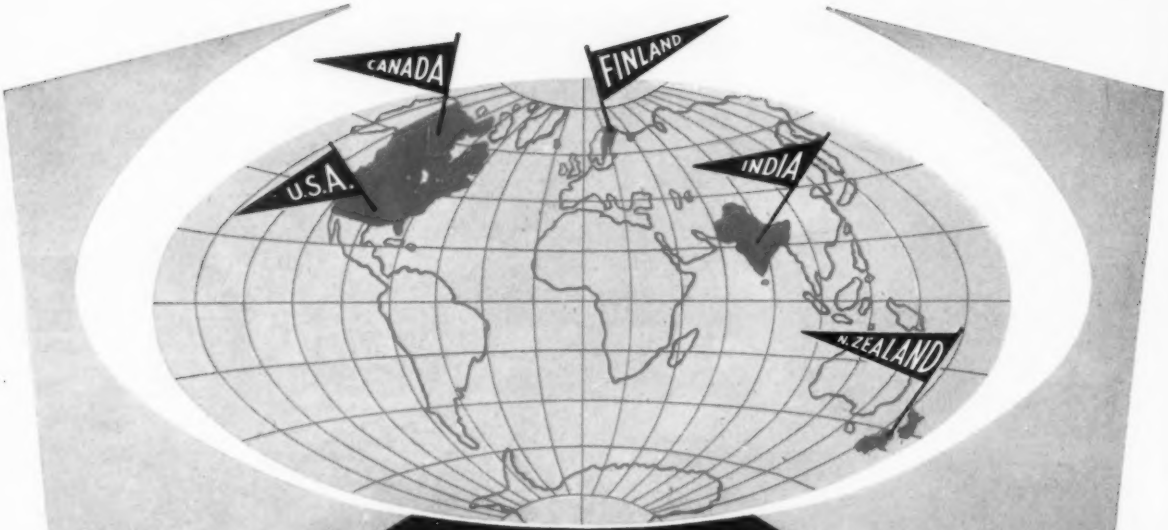
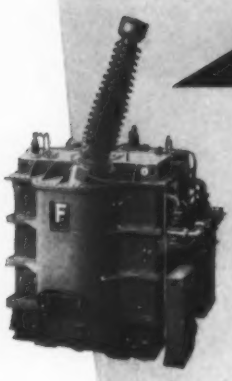


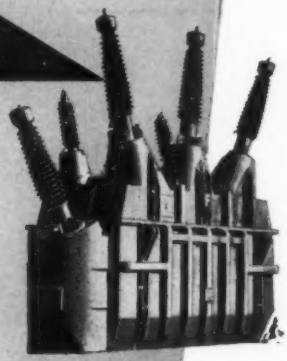
FERRANTI
TRANSFORMERS

FAMOUS THROUGHOUT THE WORLD



U.S.A. Nine 33,333 kVA, 230,000 volt single-phase Ferranti transformers are being supplied to the U.S. Army Corps of Engineers for the Garrison Dam Project, North Dakota, U.S.A. Three, forming the first 100,000 kVA bank, have been shipped.

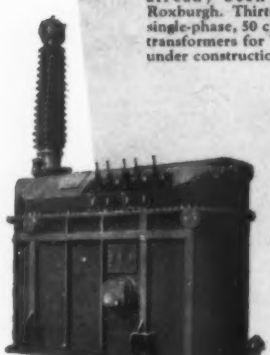
FINLAND Six 230,000 volt, three-phase Ferranti transformers have been ordered by the Imatra Power Company, Finland, for the Hikia Transforming Station and the Pyhäkoski Generating Station. Five are now in commission.

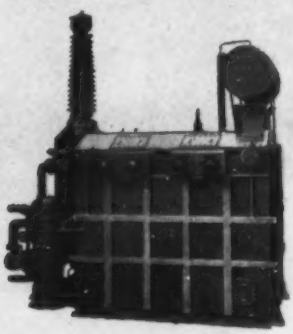


NEW ZEALAND Twenty-six Ferranti large power transformers have been ordered by the State Hydro-Electric Department of New Zealand. Thirteen 14,800 kVA, single-phase, 50 cycles, 11/220 kV transformers have already been supplied to Roxburgh. Thirteen 9,259 kVA, single-phase, 50 cycles, 11/220 kV transformers for Whakamaru are under construction.

CANADA Four 71,000 kVA, 301,400 volt single-phase Ferranti generator transformers and three 37,000 kVA, 275,000 volt step-down Ferranti transformers have been supplied to the Aluminum Company of Canada Limited for the Alcan Project at Kemano and Kitimat, British Columbia.

INDIA Three Ferranti 20,000 kVA, OFB, 3-phase, 50 cycles, 132/33.66 kV Transformers with on-load tap changing gear and two Ferranti 10,000 kVA, ON/OB, 3-phase, 50 cycles, 132/33 kV transformers with on-load tap changing gear have been supplied for the Damodar Valley Power Scheme in India.





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FT146/2

NOVA SCOTIA PENSTOCK

Engineered and installed by the Nova Scotia Power and Light Company, Ltd., this 66″ line was covered from 4′ to 17′ deep. Pipe was made by Halifax Ship Yard; pipe and couplings were bituminous coated. Wall thicknesses range from ⅜″, ½″, 9/16″ to ⅝″ for line pressures of up to 195 psi.

BIG JOB, SMALL WRENCH

From a reservoir served by the Nictaux River, 100 miles southwest of Halifax, water now flows via canal and wood stave pipe to this 3312′ Dresser-Coupled steel penstock.

The lighter weight, high-strength steel pipe was delivered to the job with Dresser Coupling middle rings and followers already in place. It was a simple matter to swing the long pipe lengths into the ditch. Then workmen put in the bolts and tightened the end nuts. *A wrench was the only joining tool required.*

That's how it is on all Dresser-Coupled jobs. No expensive skills or equipment are needed. Work can proceed in any weather at an average of only two man-minutes per bolt. And there's no need for exact pipe fitting or alignment. The resilient rubber gasket in every Dresser Coupling absorbs line stresses, strains and movement . . . permits expansion and contraction . . . keeps joints bottle-tight and trouble-free for life!

***BEFORE YOUR NEXT PENSTOCK PROJECT,* write for helpful, interesting engineering data on the many successful and varied Dresser-Coupled, steel-pipe penstock installations.**

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HOW COPCO'S NORTH UMPQUA PROJECT DELIVERS LOW-COST POWER

Eight years ago, the California Oregon Power Company was faced with a greatly accelerated load demand. To meet this challenge economically, a planned expansion program was started on the rugged, remote North Umpqua River. Today, eight new plants have provided a total addition of 145,000 kw at an exceptionally low cost.

This North Umpqua project graphically demonstrates economy of construction and operation. One central station of conventional design – Toketee – remotely controls seven unattended single-unit, outdoor-type stations within a 12-mile radius.

Five SMS turbines, with a total rated output of approximately 124,000 hp, are used in this project. SMS accessories in five of these stations include 7 Howell-Bunger Valves – 3 of which shown in the diagram interconnected with the Toketee turbines – 6 Butterfly Valves, 2 Elbow-type Pressure Regulators and 2 Motor-operated Trash Rakes. All are now in operation and exceeding guaranteed performance. To get full information on hydraulic turbines and accessories, contact us at York, Pennsylvania.

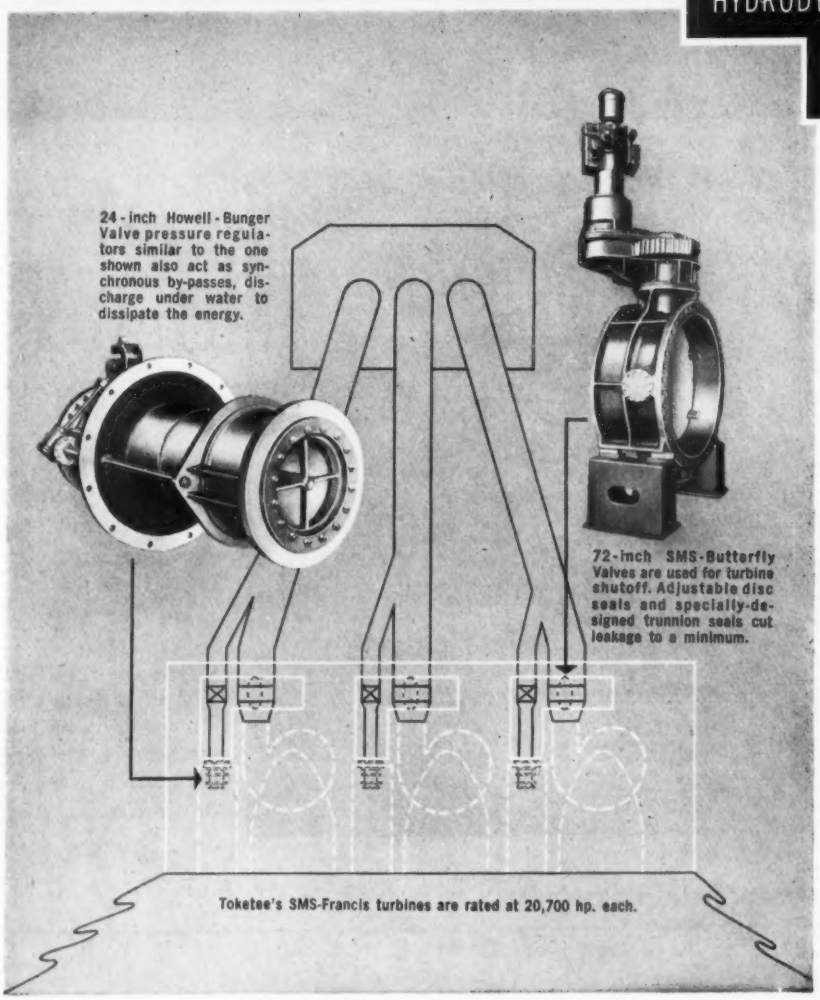
HYDRAULIC TURBINES
PUMPS
GATES & HOISTS
TRASH RAKES
ACCESSORIES
HYDRODYNAMICS
ROTOVALVES
BALL VALVES
BUTTERFLY VALVES
FREE-DISCHARGE VALVES
CONTROLLABLE-PITCH SHIP PROPELLERS

S. MORGAN SMITH

AFFILIATE: S. MORGAN SMITH, CANADA, LIMITED, TORONTO
Licensees: The Harland Engineering Company, Ltd., Alloa, Scotland
Dengyosha Prime Mover Works, Ltd., Japan

A single main penstock with a surge chamber feeds 3 SMS-Francis turbines operating under a 433-foot net head at Toketee. Consultants for the North Umpqua project: Pioneer Service and Engineering Company.

HYDRODYNAMICS


24-inch Howell-Bunger Valve pressure regulators similar to the one shown also act as synchronous by-passes, discharge under water to dissipate the energy.
72-inch SMS-Butterfly Valves are used for turbine shutoff. Adjustable disc seals and specially-designed trunnion seals cut leakage to a minimum.
Toketee's SMS-Francis turbines are rated at 20,700 hp. each.

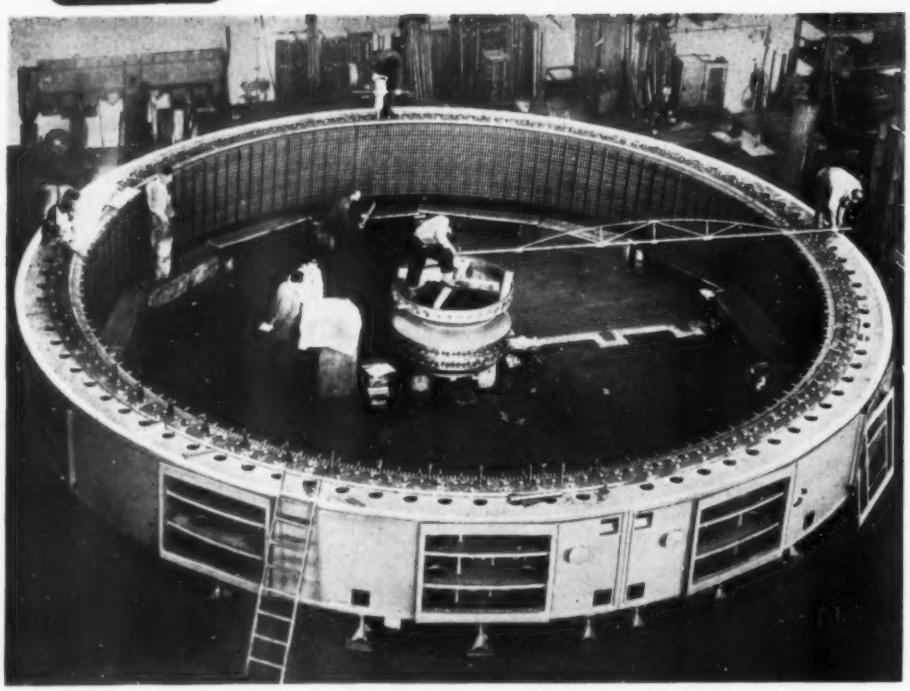
Dual control arrangement of the Howell-Bunger Valves at Toketee makes it possible to pass a constant predetermined quantity of water regardless of turbine load. This helps control the down-river water level.

MADE IN AUSTRIA

this is

the model of the Vienna State Opera as it now appears after reconstruction. The reopening took place in November, 1955.

ELIN



and that is

the stator of a vertical-shaft low-speed alternator for Jochenstein Power Station.

Overall diameter 11.7m. (38.4ft.)

Jochenstein Power Station, situated where the Danube forms the border between Germany and Austria, is a joint Austro-German Project

"ELIN"
VIENNA AUSTRIA

AKTIENGESELLSCHAFT FÜR ELEKTRISCHE INDUSTRIE

LOCOS WITH A 'RECORD-BREAKING' PERFORMANCE

557 feet of tunnel (8′ 6″ bed width) was recently driven through rock in seven days — a world record! The tough job of haulage was, of course, handled by Ruston diesel locos

The tunnelling record was achieved by the Mitchell Construction Co. of Peterborough on one of their contracts for the North of Scotland Hydro-Electric Board. Consulting Engineers: Sir Murdoch MacDonald & Partners, London.

EASE OF CONTROL · LOW MAINTENANCE · DEPENDABILITY
these are some of the qualities which make

RUSTON

narrow-gauge
diesel locomotives
a natural choice for heavy haulage

RUSTON & HORNSBY LTD · LINCOLN · ENGLAND

ASSOCIATED WITH DAVEY, PAXMAN & CO. LTD., COLCHESTER

CLUTHA DIVERTED BEFORE ZERO

The Clutha River was turned into its new course through the diversion channel of the Roxburgh hydro-electric project at 6.10 a.m. yesterday, 18 hours after the first rubble had been pushed into the stream, and six hours ahead of schedule.

Yet at 9 p.m. the day the work began, the whole operation was nearly abandoned because of a rising river and discouraging weather reports.

THIS HIGH-LEVEL DRAMA WAS ENACTED WHILE THE BULLDOZER TEAM WAS STILL STRUGGLING TO DEFEAT THE RISING WATERS

victory over time and flood

Eleven Caterpillar Tractors with Birtley bulldozers fought unceasingly against the rising flood of New Zealand's great Otago River and beat the time schedule by 6 hours "None . . . . . faltered for one moment", announced the contractors. Triumphant proof indeed of the thorough reliability of Birtley Caterpillar Equipment.

you can rely on

BIRTLEY

EQUIPMENT MADE TO CATERPILLAR DESIGN AND SPECIFICATIONS

SOLD AND SERVICED THROUGHOUT THE WORLD BY THE AUTHORISED CATERPILLAR DEALER ORGANISATION

THE BIRTLEY COMPANY LTD BIRTLEY COUNTY DURHAM ENGLAND

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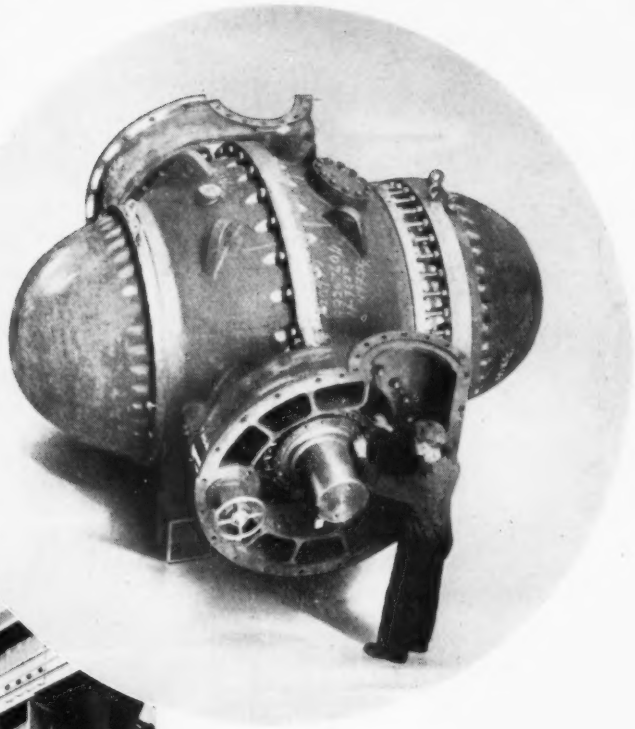
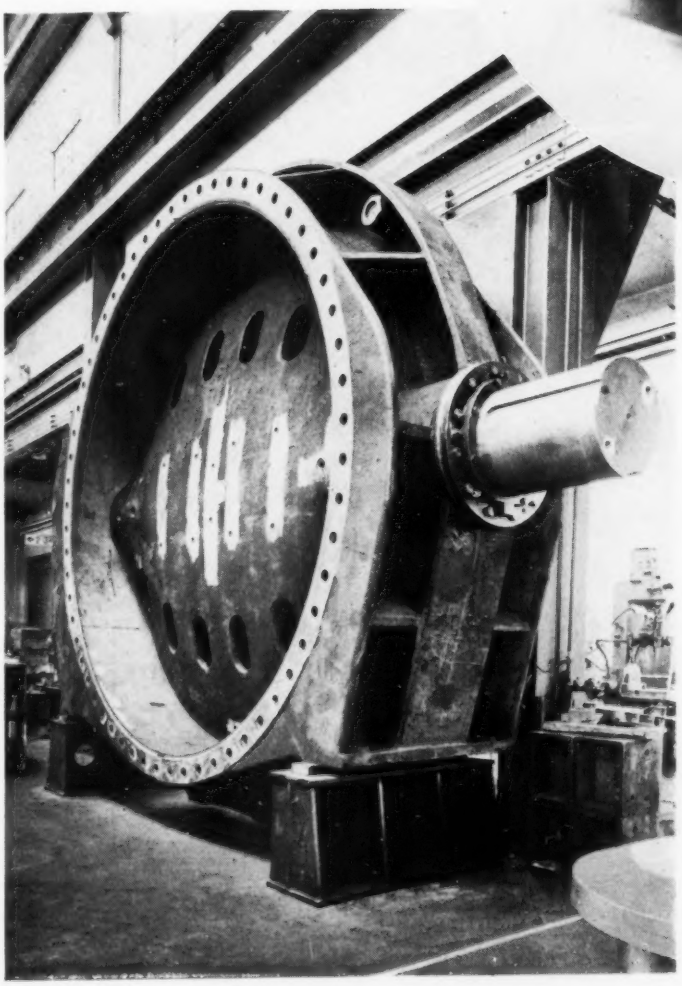
TURBINE VALVES





Above :

THE 59″ DIA. ROTARY VALVE

for the KMW Turbine installed in the Swedish Power Station of Tåsan in Värmland (turbine output: 48,200 H.P. at a head of 856 feet).

To the left :

THE 151″ DIA. BUTTERFLY VALVE

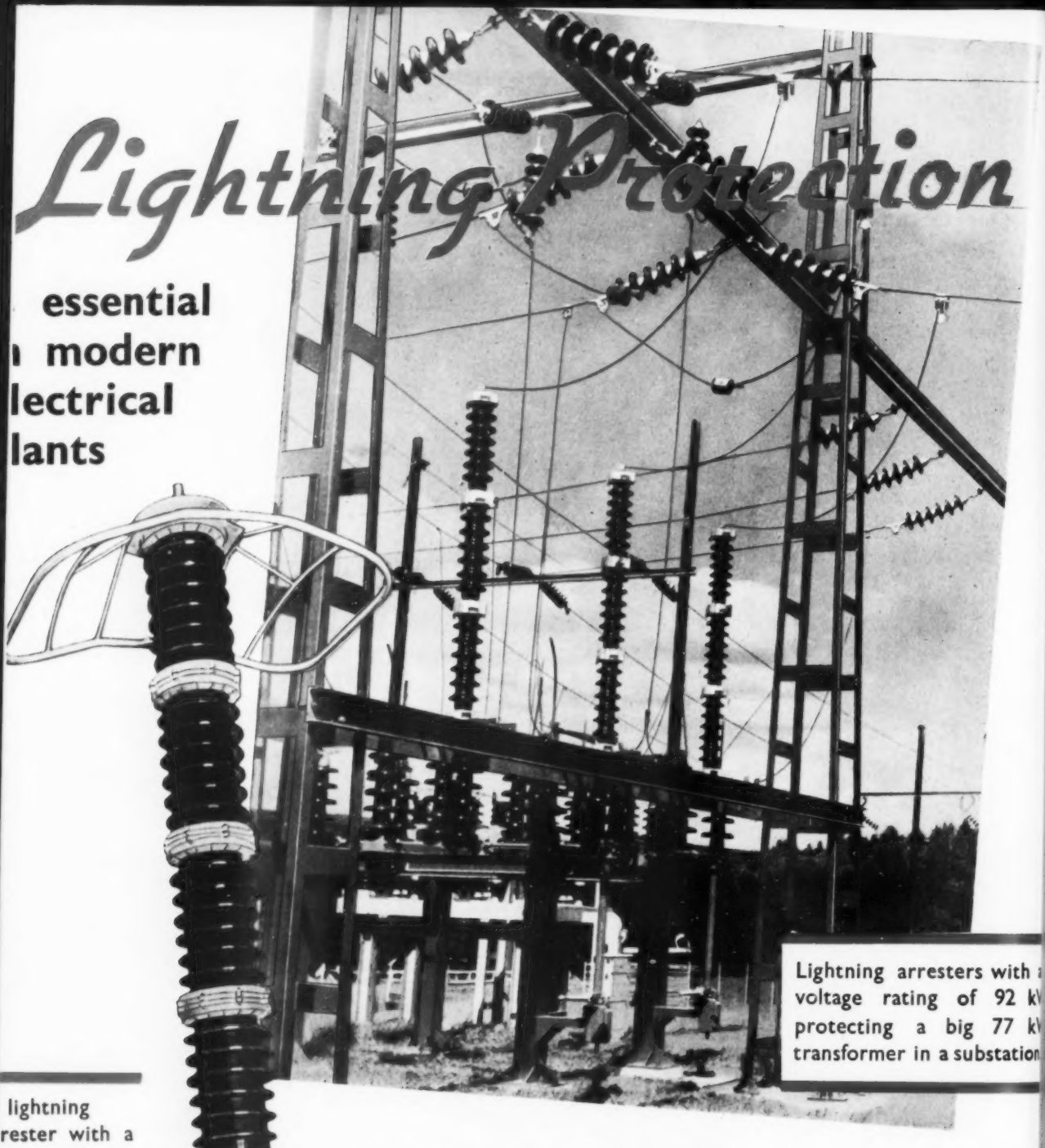
for one of the four KMW Turbines installed in the Spanish power station of San Esteban, belonging to the Saltos del Sil, S.A., Madrid (output of each turbine: 90,700 H.P. at a head of 338 feet).

AKTIEBOLAGET KARLSTADS MEKANISKA WERKSTAD

Karlstad · Sweden

Lightning Protection

essential
modern
lectrical
lants



Lightning arresters with a voltage rating of 92 kV protecting a big 77 kV transformer in a substation

lightning
rester with a
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his type is
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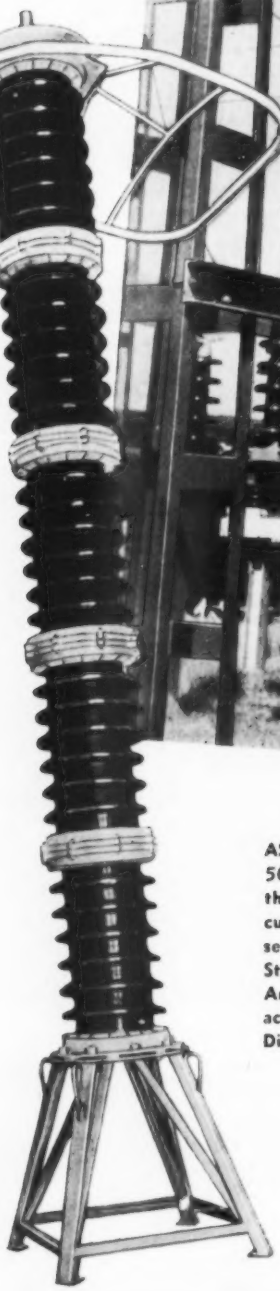

ASEA's lightning arresters cover the range 500—400,000 V and are manufactured in three different series according to their current rating: a heavy duty and a standard series tested according to the American Standards AIEE 28 A 1950 for Station Arresters (10,000 A) and a light series tested according to the same Standards for Line and Distribution Arresters (5,000 A)

Outstanding features: Low spark-over lev at high impulse steepness. Low dischar voltage. Precision in manufacture: dischar voltage guaranteed to ± 5 per cent. Perfe sealing. Built as a self-supporting column t to the highest ratings, with consequent lo installation costs. It is cheaper in the lon run to install ASEA's efficient lightnin arresters and avoid expensive repairs an service interruptions due to damaged equip ment and blown high voltage fuses. For a your lightning protection problems — consul

Västerås **ASEA** Sweden

MUCONE POWER STATION
No. 1, ITALY

PENSTOCKS IN COURSE
OF ERECTION

Head—752 metres
Diameter—2·50-2·20-2·00 metres

DESIGNERS AND MANUFACTURERS OF THE MOST MODERN AND POWERFUL HIGH PRESSURE PIPE-LINES WITH A WORLD WIDE REPUTATION

★

EARLY DELIVERY

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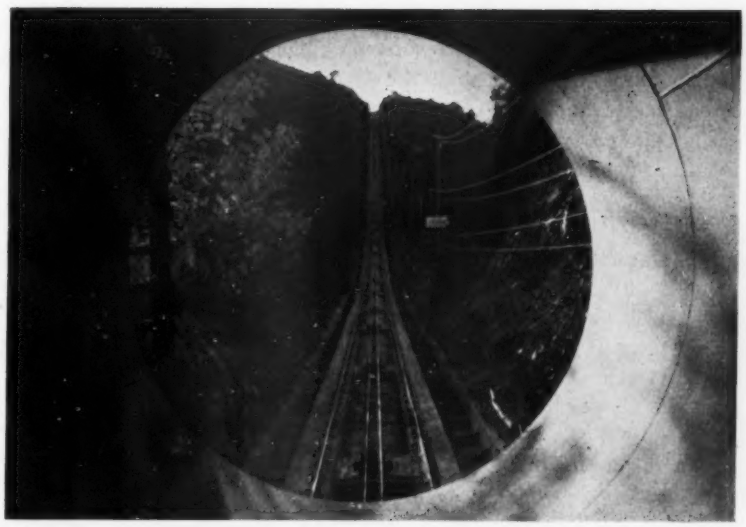

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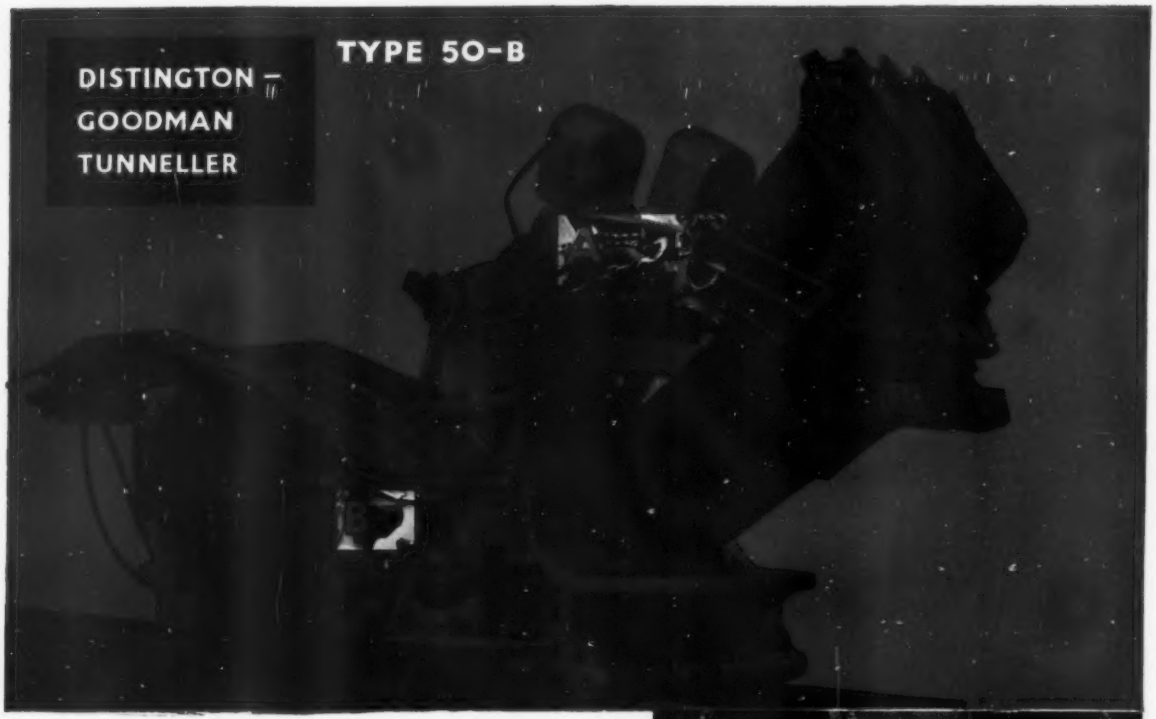


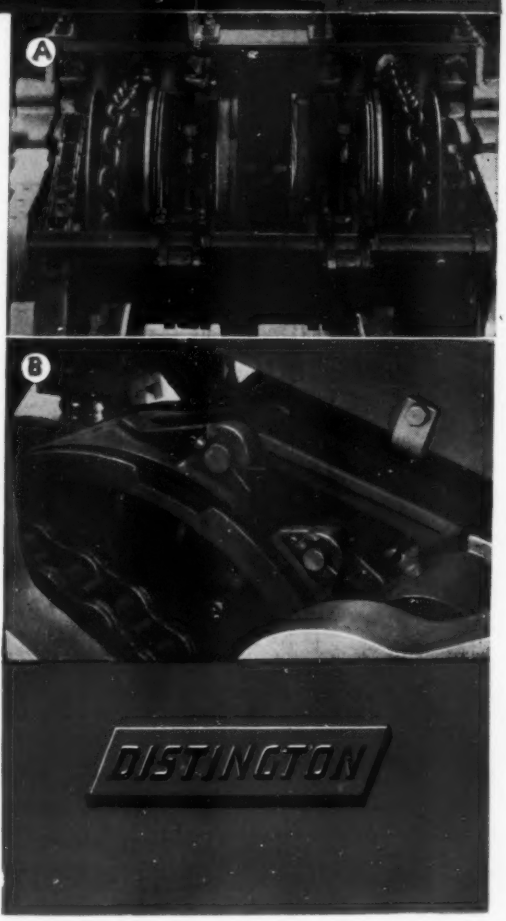
This machine driven by a 70 h.p. flameproof motor, has all its movements (forward and reverse tramming, and hoisting and swinging the boom and shovel) controlled by two hand levers and two foot pedals. Each pedal and lever operates an easily adjusted brake band on a planetary gear drum. There is adequate mechanical and electrical protection against overload.

Power transmission to the planetary gears is by roller chain.

The machine is very heavily constructed and, with its simple safe control, is comparatively insensitive to hard usage. The Distington-Goodman range of tunnellers also includes 75 h.p. and 100 h.p. machines; please write for more details.

70 h.p. motor (AC or DC). Dipper capacity—13 cu. ft.
6 loading cycles per min. Loading capacity—81 cu. ft. per min.
Tramming speed—176 f.p.m. forward, 120 f.p.m. reverse

BOOM LENGTH	CLEAN-UP AT TRACK LEVEL	OPERATING HEIGHT
5′	13′	8′ 8″
6′	14′ 6″	9′ 8″



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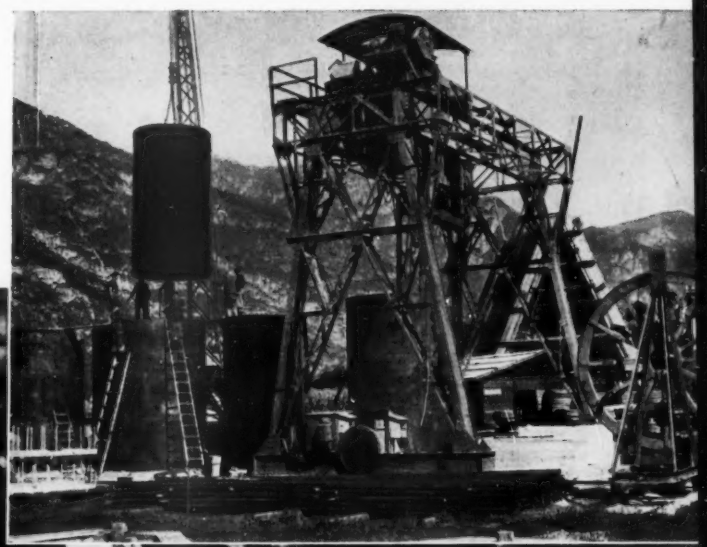
GT5

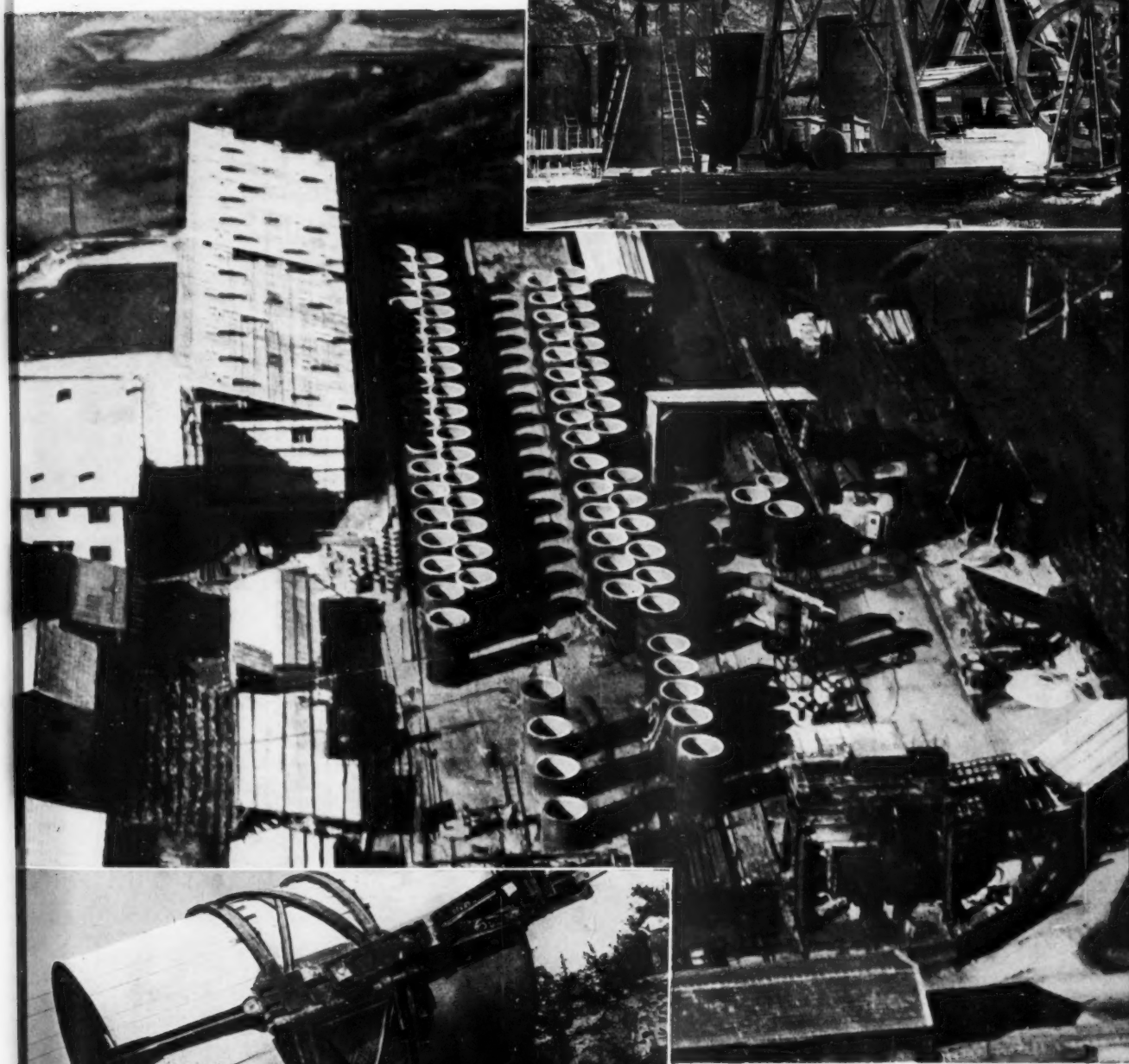
SACAIM

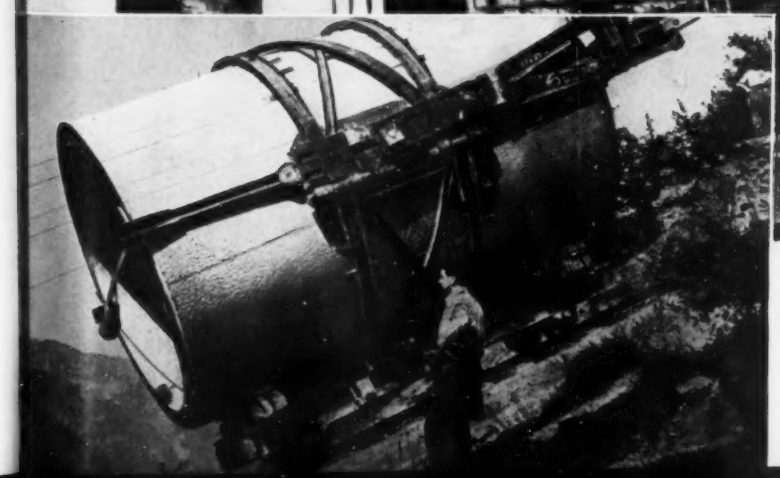
Soc. p. Az. Cementi Armati Ing. Mante

VENICE (ITALY) - Accademia 979/A - Telephone 24.

Normal, special and prestressed reinforced concrete penstocks of any diameter and pressure.







Main power penstock of prestressed reinforced concrete made for S.A.D.E Soverzene Station and in service since 1950.

(Diameter 8 ft. 6 ins. - Pressure 427 lb. per sq. in

engineering begins early...

Some day these lads may be pitting trained engineering skills against nature in remote places . . . harnessing the power of rivers . . . conserving water for irrigation and many other uses . . . helping to build a nation's economy through planned development of natural resources.

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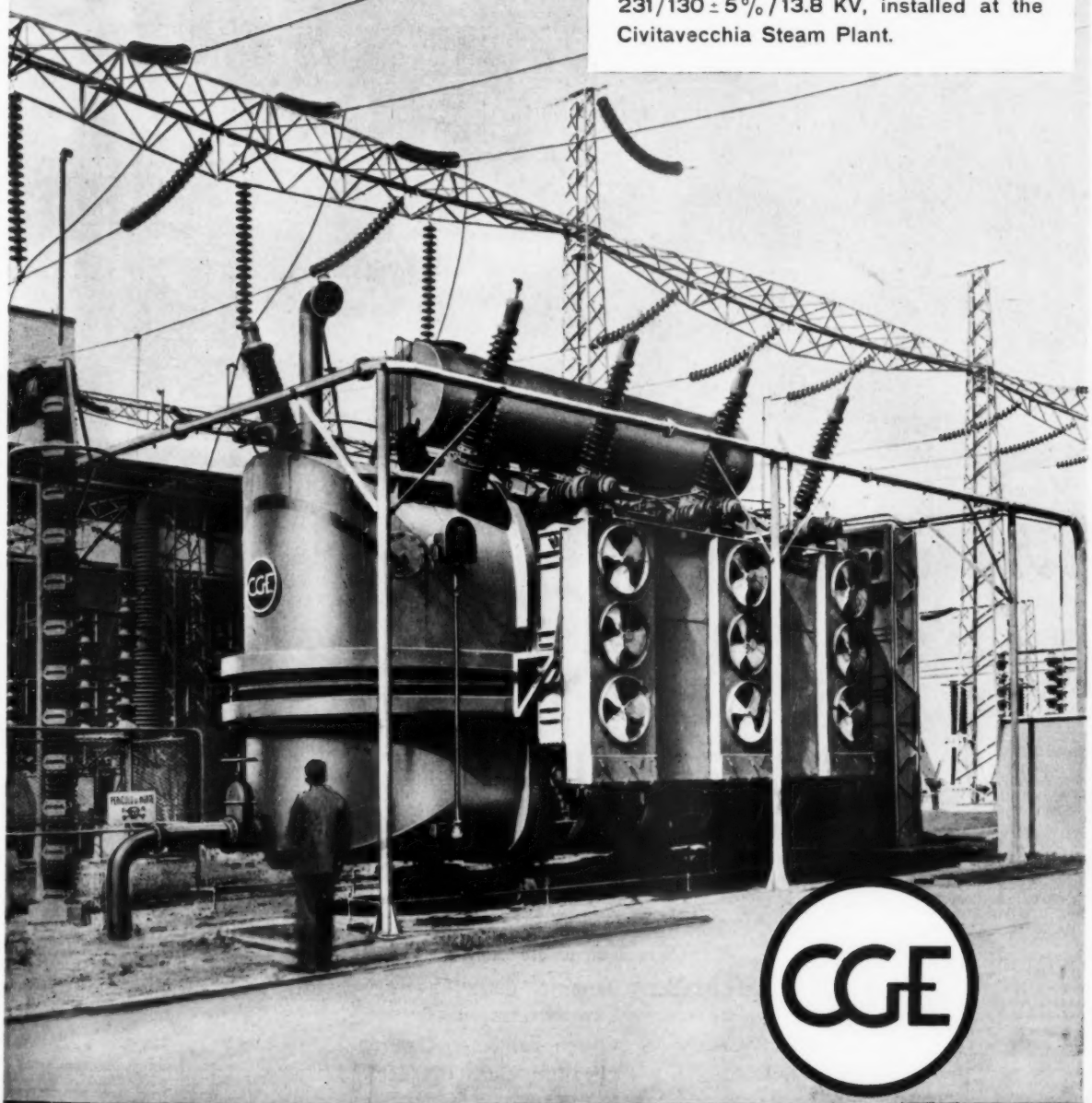

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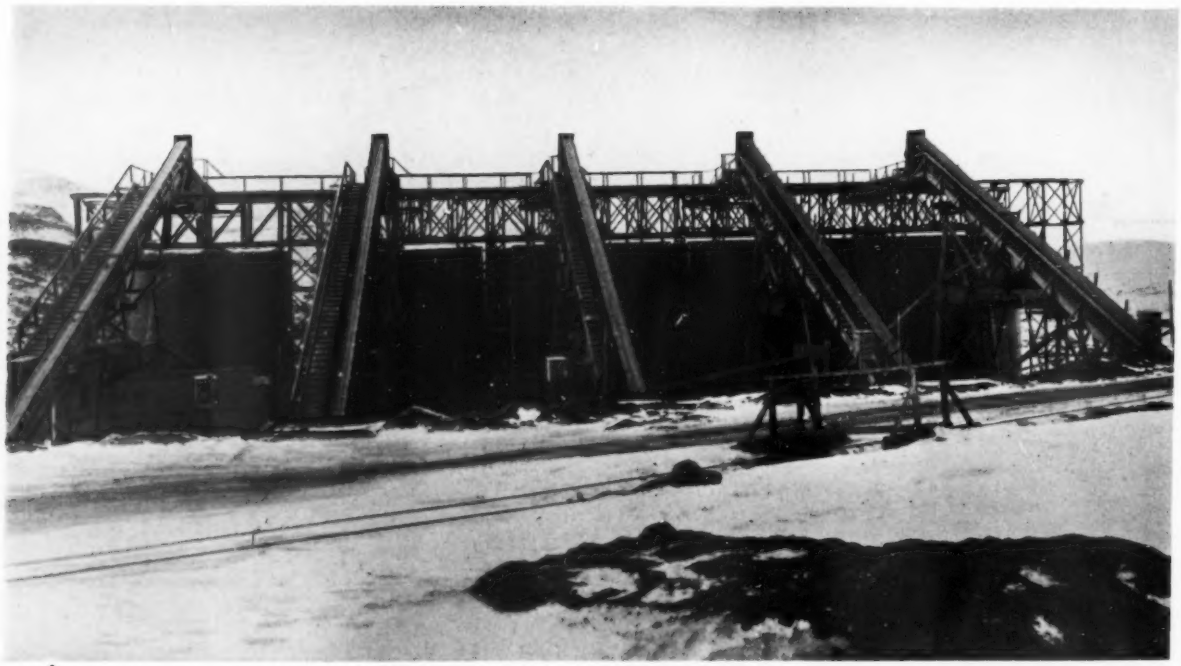

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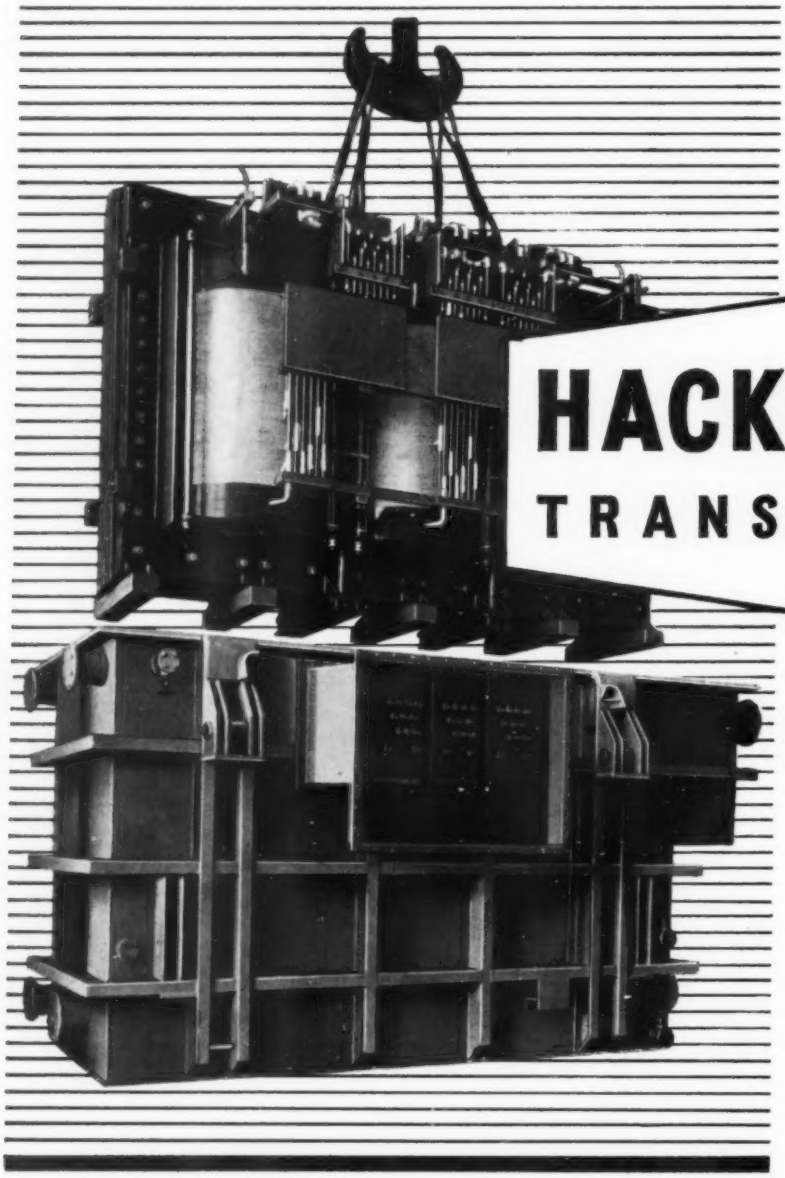

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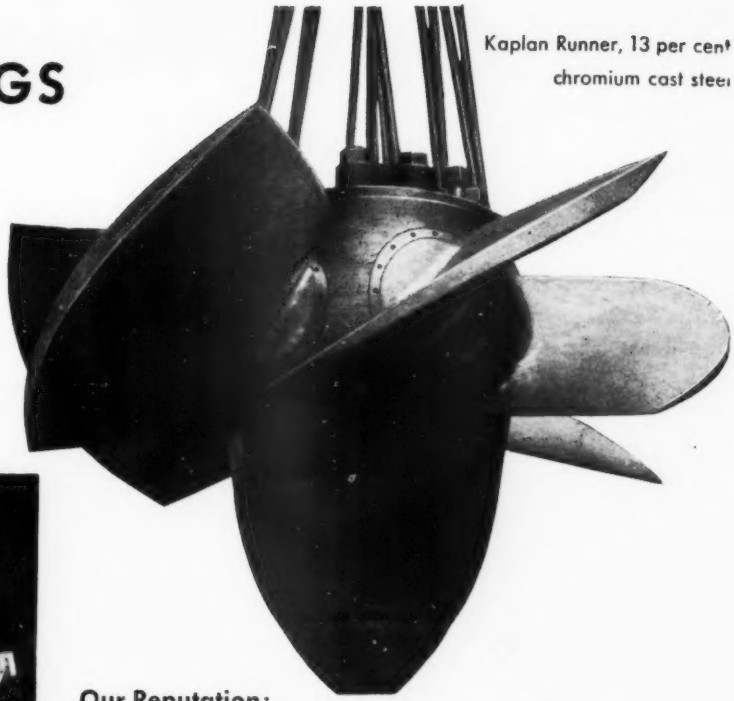

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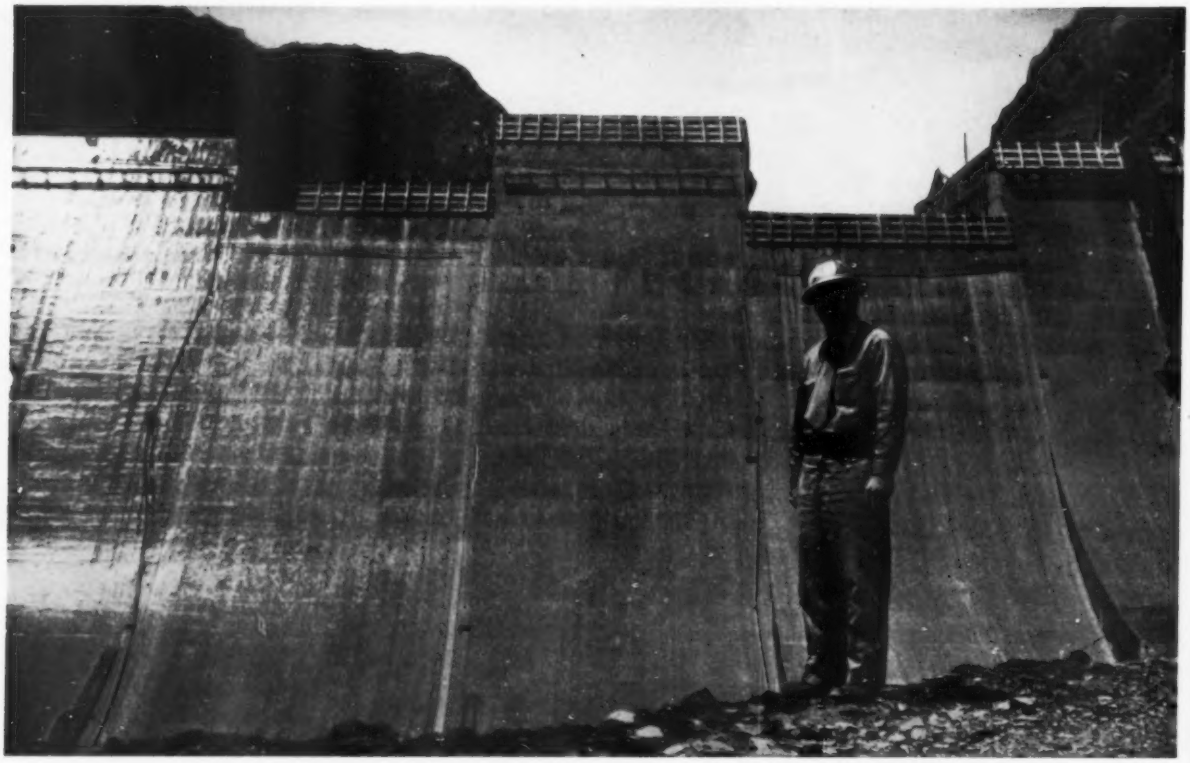

Hundreds of Atlas Copco rock drills, together with Atlas Copco rock breakers, pneumatic pushers, compressors and Sandvik Coromant drill steels, are in action on large-scale quarrying, excavating and tunnelling operations for Turkey's biggest hydro-electric project. It is at Sariyar on the Sakarya River, about 150 km. west of Ankara. A huge power station will have an initial capacity of 80,000 kilowatts and the project is expected to be finished by 1957.

50 DRILLS QUARRY ROCK FOR DAM

Rock for a concrete gravity dam 330 feet high and 820 feet wide across the top is being supplied from a nearby stone quarry. By the time the dam is completed 650,000 cu. yards of rock will have been quarried. This work is mainly being done with fifty Atlas Copco rock drills. The drills are fitted with Sandvik Coromant tungsten-carbide-tipped steels. The dam is being built for Etibank, and the construction supervisors are Chas. T. Main, Inc.

Besides the dam, Atlas Copco equipment and Sandvik Coromant steels are being used on the surge tank, penstocks and two tunnels. The first one, 7,000 feet long and 30 feet in diameter, is completed. The second, to be 3,100 feet long and also 30 feet in diameter, was started in the middle of 1954 and almost half-completed by the end of that year.

POOR ROCK STOPS TUNNEL WORK

With unexpectedly poor rock formations, hold-ups were many. In the first tunnel a cave above the outlet side caused a collapse of earth and rock, blocking the tunnel and delaying further work for six months. But when conditions permitted a full face advance, as many as thirteen Atlas Copco light rock drills were in action at one and the same time in a comparatively small drilling area.

MORE DRILLS AND FASTER TIMES

Atlas Copco light rock drills are compact, *one-man* machines. That saves space; means *more* drills at the face and, consequently, *faster* drilling times each round. Atlas Copco rock drills with Sandvik Coromant steels are an unbeatable *lightweight* drilling unit. In ten years it has extensively replaced heavy equipment to become the world's most widely-used rock-drilling combination.

EXTRA TOUGH DRILL STEELS

Atlas Copco rock drills were developed to work with Sandvik Coromant steels. Sandvik, to maintain a never-varying drill steel quality, control every phase of production—from the mining of iron ore, processing of wolfram ore to the final, *extra-tough* tungsten-carbide inserts used throughout the world wherever Atlas Copco rock drills are in action.

Main contractors on the Sariyar project are Philipp Holzmann A.G., Hochief A.G., Siemens Bauunion G.m.b.H., and Rar Türk Limited. Sosyetesi.

The Atlas Copco Group puts compressed air to work for the world. It embraces thirty-one Atlas Copco companies and twenty-four agents, manufacturing or selling and servicing Atlas Copco equipment in more than 50 countries throughout the world.

Entrance of first diversion tunnel. Tunnelling is taking place from jumbos, mobile drilling platforms developed by Atlas Copco, following patterns drawn up by their Project Department.

Fifty Atlas Copco rock drills fitted with Sandvik Coromant steels were used to drill 650,000 cu. yards of rock for the dam.

For further details about Atlas Copco equipment write to the most convenient of the addresses given here:

UNITED KINGDOM, Atlas Copco (Great Britain) Ltd., Wembley, Middx; FRANCE, Atlas Copco France S.A., 29, Rue Marbeuf, Paris 8e; HOLLAND, Atlas Copco Holland N.V., P.O. Box 6056, Rotterdam; ITALY, Atlas Copco Italia S.p.A., Viale Marche 15, Milan.
CANADA, Atlas Copco Canada Ltd., Montreal, A.M.F., P.Q.; AUSTRALIA, Atlas Copco Australia Pty. Ltd., P.O. Box 54, Auburn, N.S.W.; SOUTH AFRICA, Delfos & Atlas Copco (Pty.) Ltd., P.O. Box 504, Benoni, Transvaal; U.S.A., Atlas Copco Pacific Inc., 930, Brittan Avenue, San Carlos, California; Atlas Copco Eastern Inc., P.O. Box 2568, Paterson 2, N.J.

Readers in countries outside those listed above and who do not know the name of their local Atlas Copco company or agent, please write to Atlas Copco AB, Stockholm 1, Sweden.

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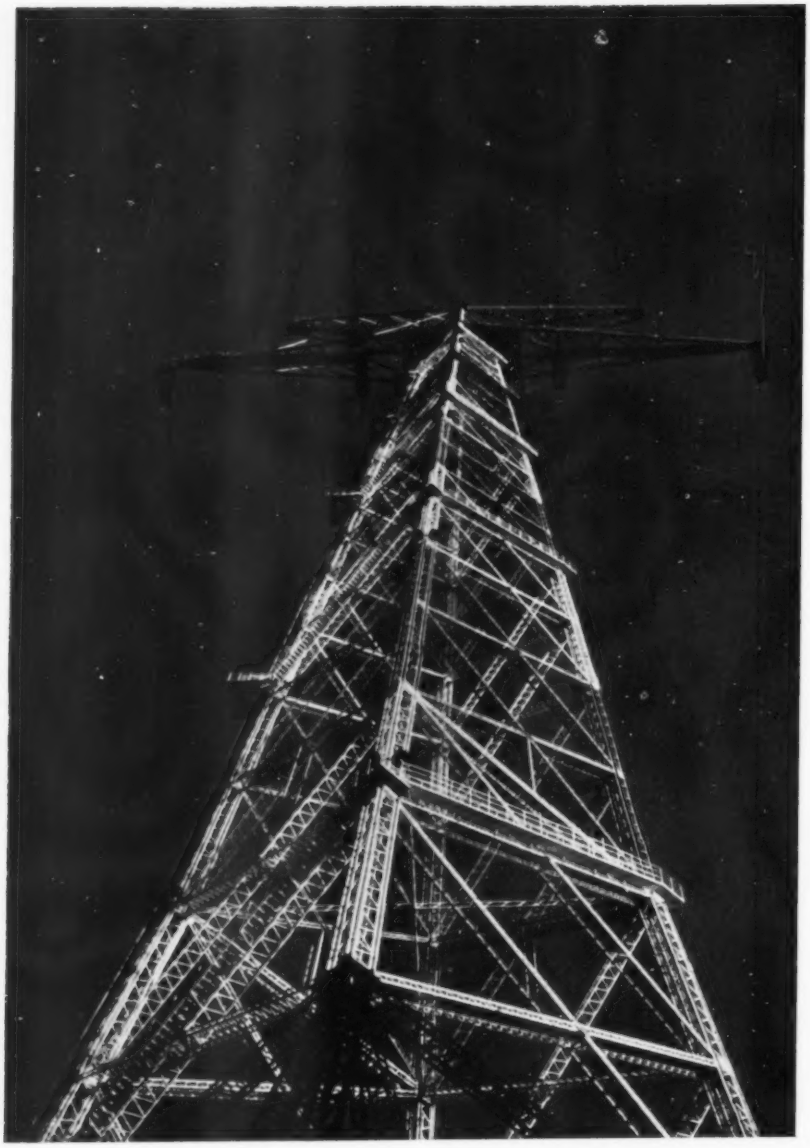

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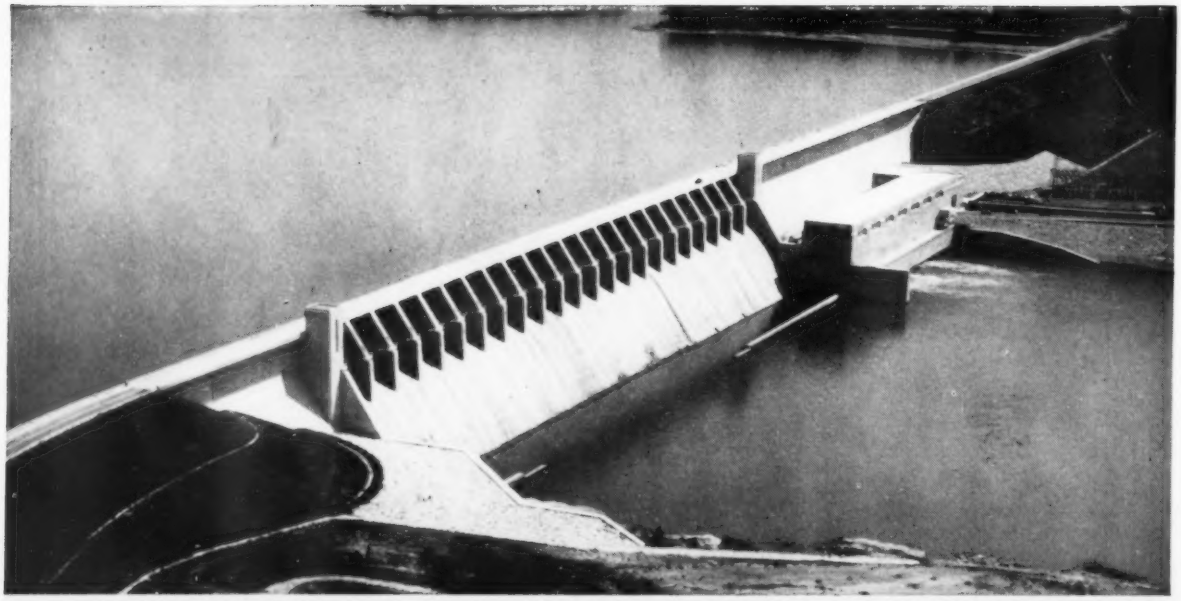

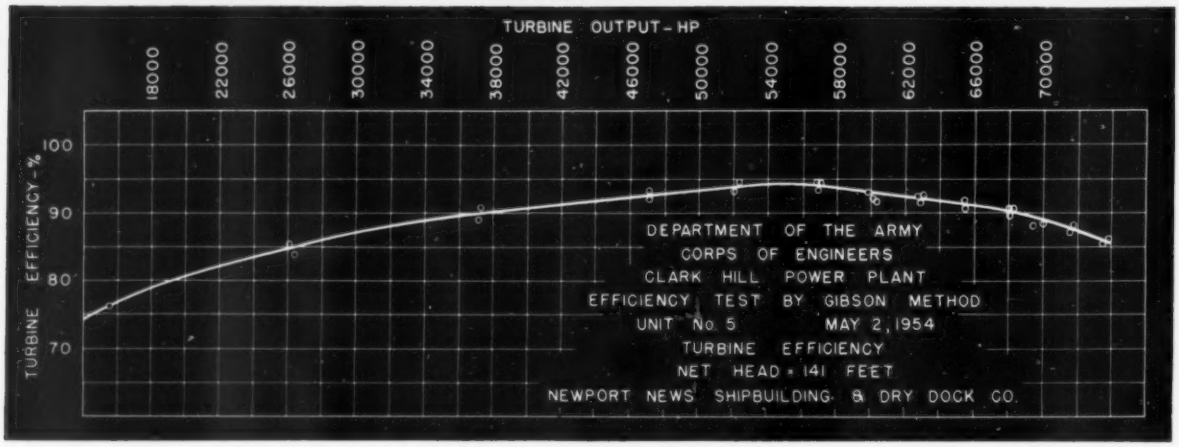

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Reflects advanced practices at Newport News

THE GRAPH shows performance of a 55,000 horsepower turbine, one of seven such units built by Newport News for the Clark Hill Power Plant (see photo).

Shape of the curve is typical . . . not exceptional . . . for Newport News turbine performance. Regular, uniform, showing no-cut-off at full load, it indicates consistent delivery and stable operation.

And especially, experience in design and model testing.

At Newport News, turbine runners are continually being designed and redesigned for improvements in performance. And often upon receiving a contract for turbines, a model setting is built and complete tests made. So far, Newport News has filled turbine contracts with an aggregate rated output in excess of 7,000,000 horsepower.

Penstocks, spiral casings, valves, pumps, rack rakes and other essentials are also designed and built by Newport News. Our illustrated booklet, "WATER POWER EQUIPMENT," will be sent to you upon request.

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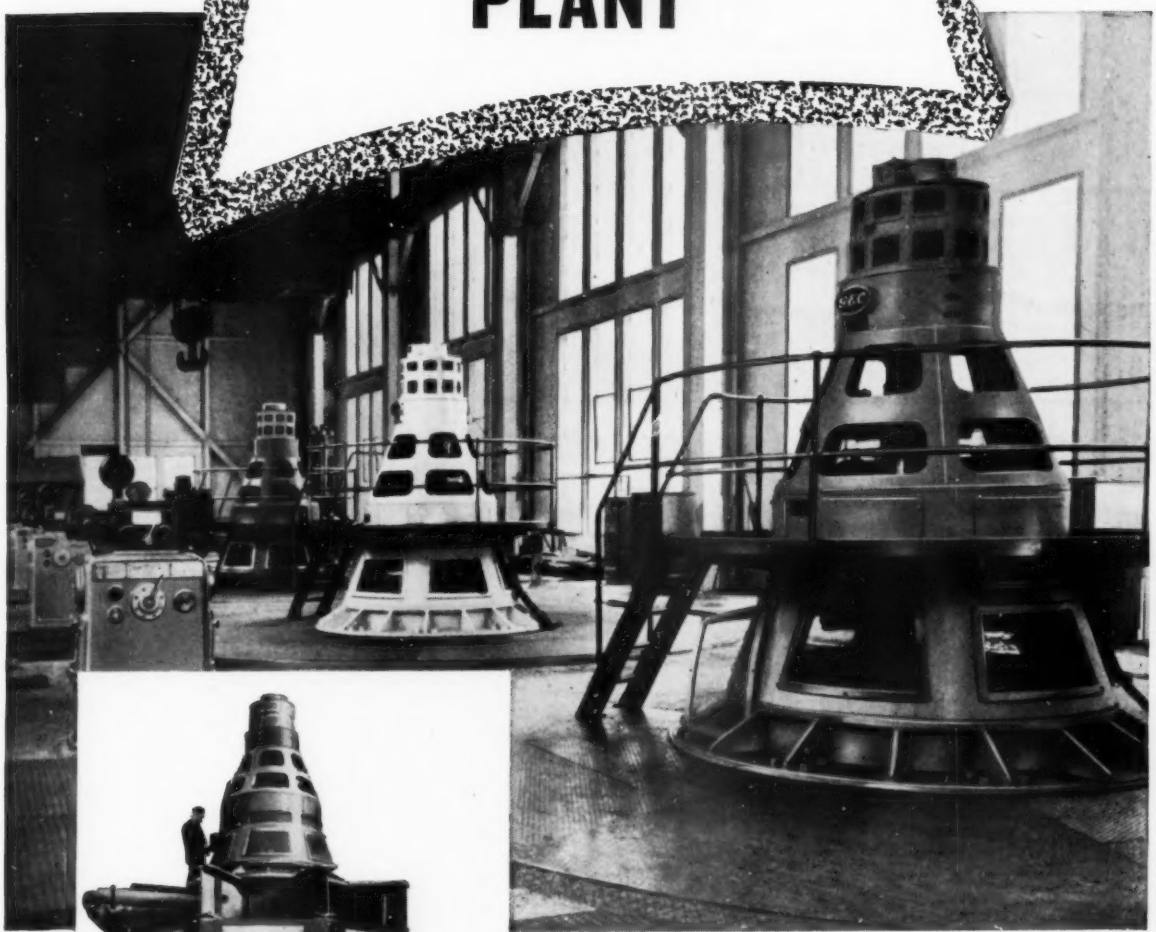
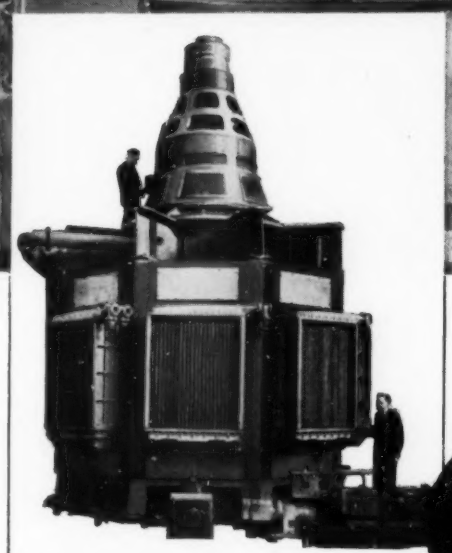


Three of five 25 MW, 11 kV., 600 r.p.m. sets in the Tungatinah Power Station, Tasmania.



One of the above alternators erected for test.

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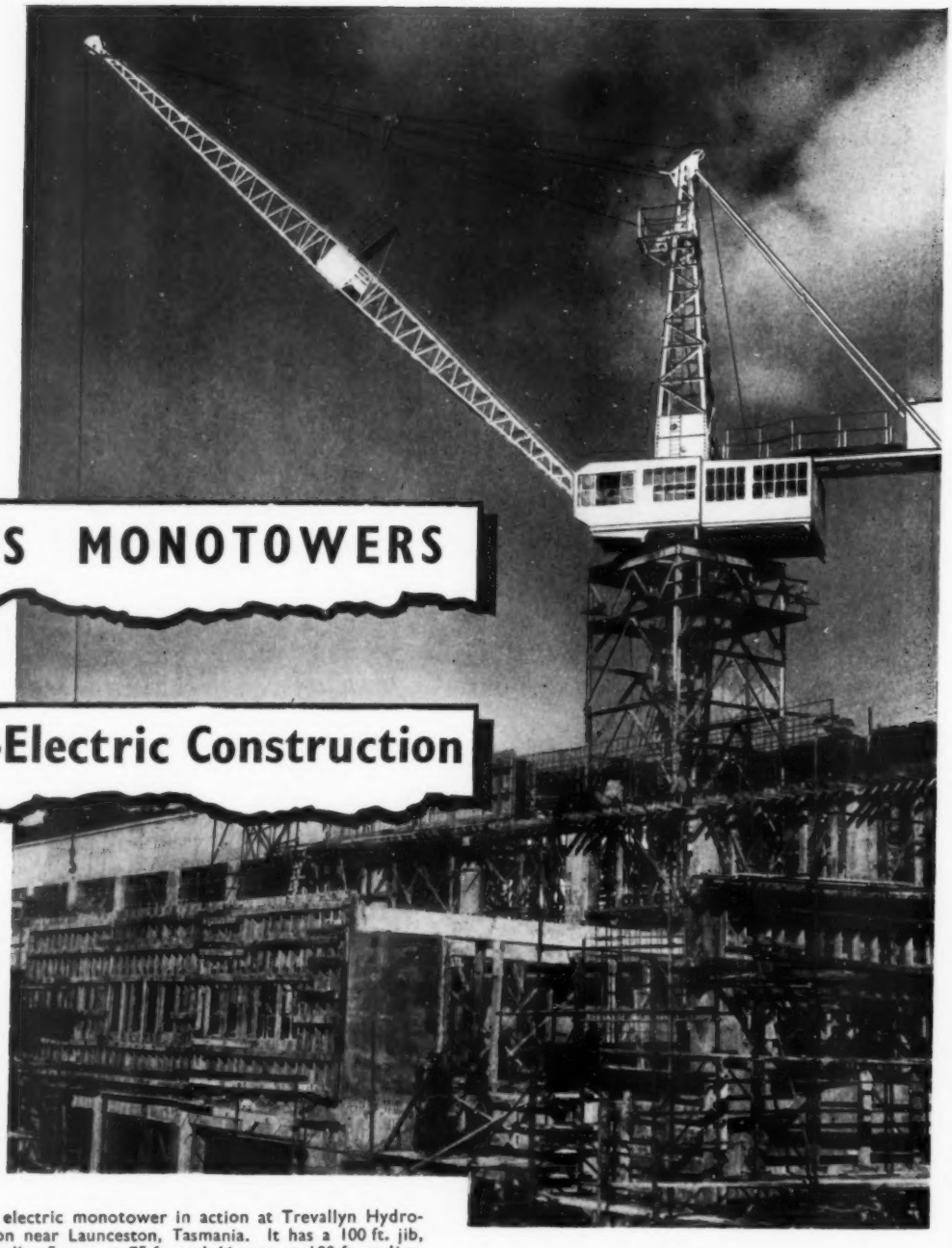

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This crane is a 5 ton electric monotower in action at Trevallyn Hydro-Electric Power Station near Launceston, Tasmania. It has a 100 ft. jib, 80 ft. tower, and handles 5 tons at 75 ft. and 1¼ tons at 100 ft. radius. The ideal crane for erection of dams and high buildings generally, with all the dependability of the Butters product.

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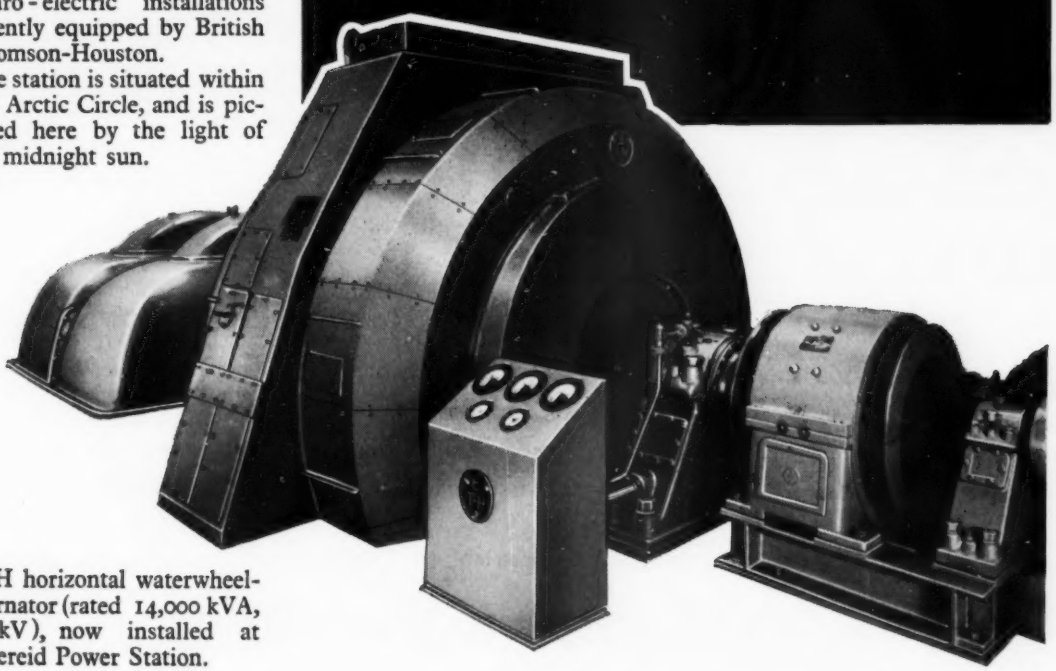
inside the Arctic Circle

Hydro-electric Equipment at Oldereid power station, Norway

One of several new Norwegian hydro-electric installations recently equipped by British Thomson-Houston.
The station is situated within the Arctic Circle, and is pictured here by the light of the midnight sun.



BTH horizontal waterwheel-alternator (rated 14,000 kVA, 6.6 kV), now installed at Oldereid Power Station.

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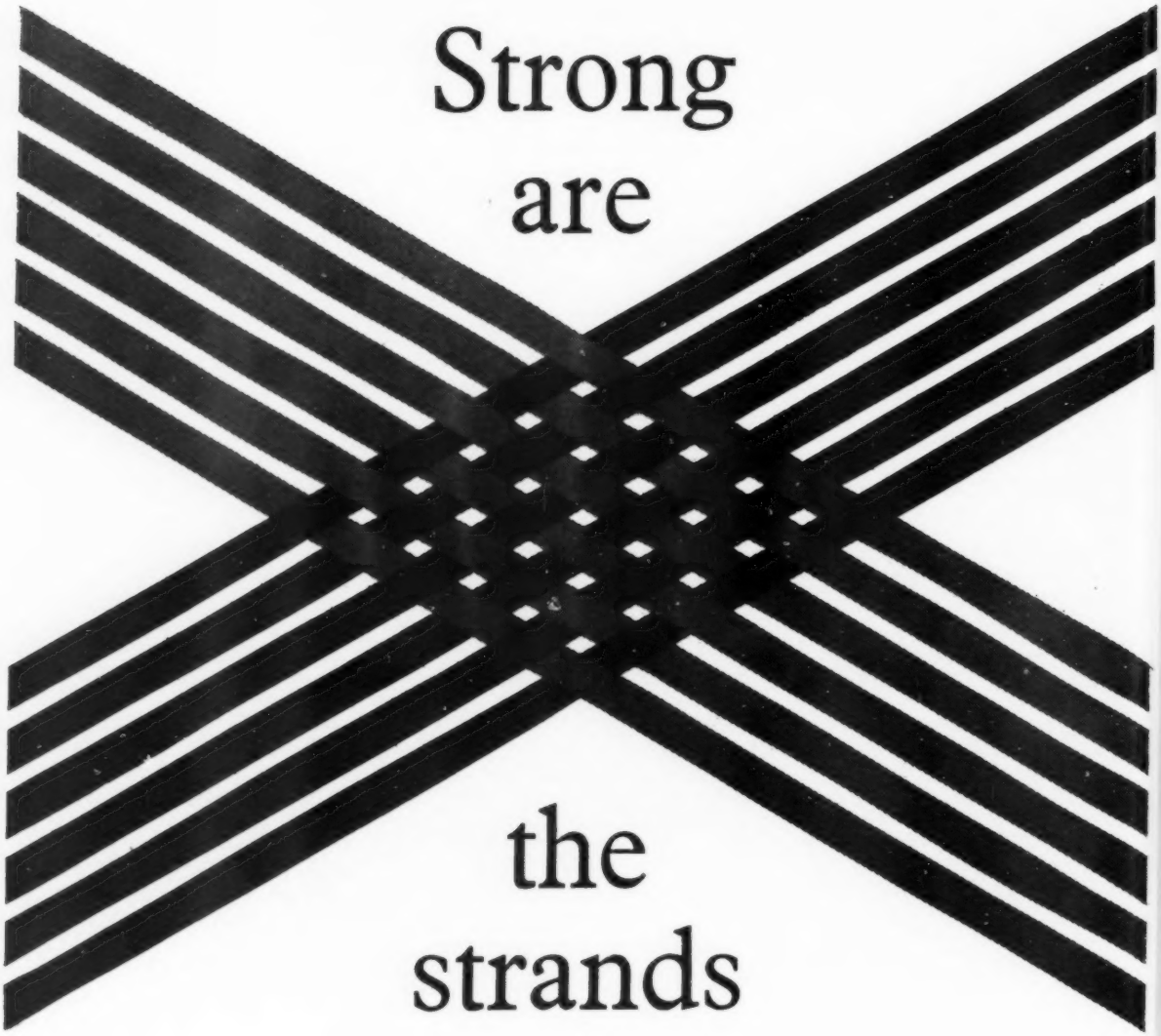

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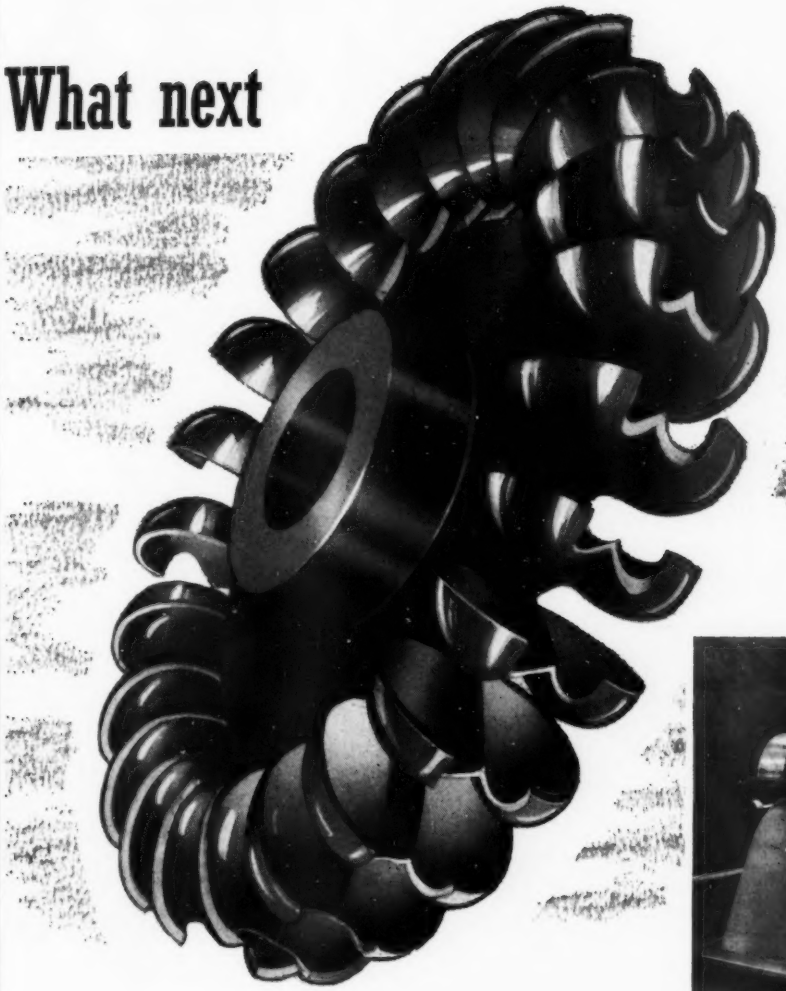

Casting this water turbine runner in a single piece from aluminium-bronze was a considerable achievement. Birkett, Billington & Newton were able to tackle the job because they have specialised in the development of this metal, and their unrivalled experience and facilities enable them to carry out such problematic non-ferrous castings. Aluminium-bronze has a high yield point and a low weight/strength ratio, and is very resistant to shock, erosion, corrosion and abrasion.

The runner and other castings have been made by Birkett, Billington and Newton for this 750 H.P. Pelton Wheel Generator supplied to the New Zealand Government by Gilbert Gilkes and Gordon Ltd., of Kendal.

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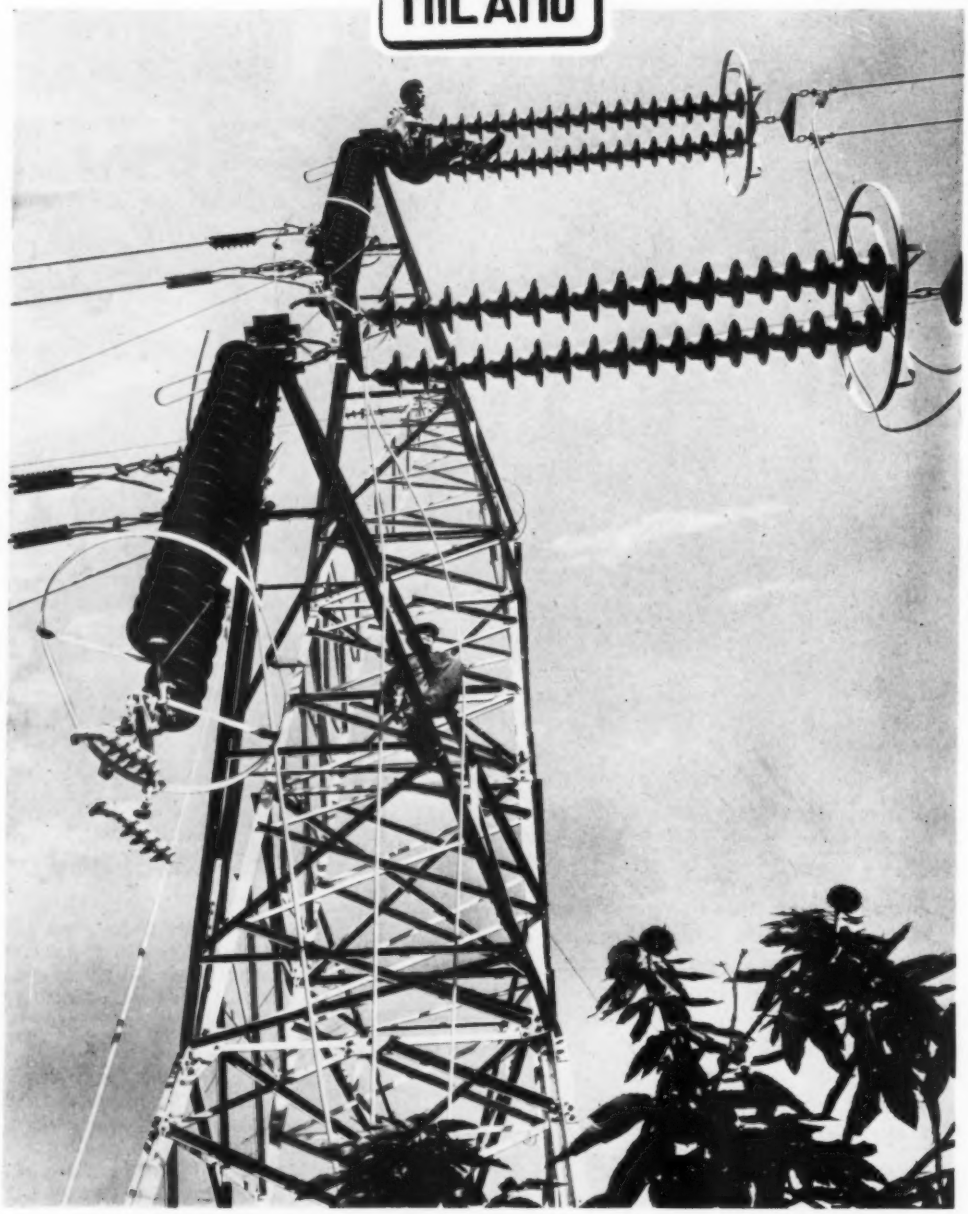

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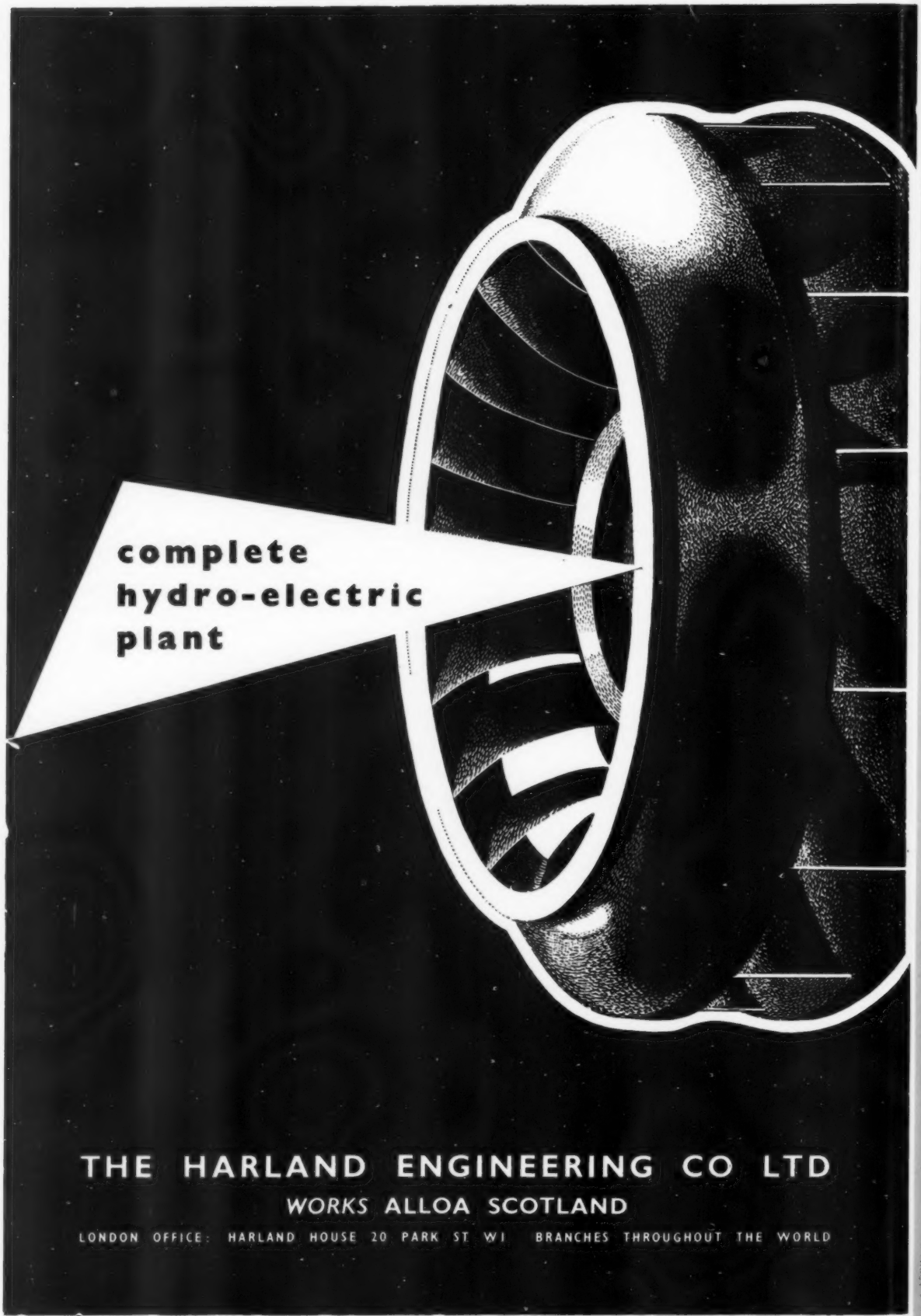
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WATER POWER

A technical journal devoted to the study of all aspects of Hydro-electric developments

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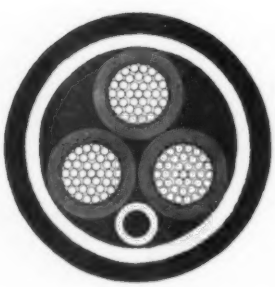

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WATER POWER

A technical journal devoted to the study of all aspects of Hydro-Electric Development

Solar Energy and Water Power

IN the last 12 months, the sun has risen, so to speak, over the engineering horizon with a new radiance.

Man has always utilised solar energy, mainly indirectly; and indeed, in the hydro-electric world, we are entirely dependent on the sun in the sense that its warmth is the underlying source of power to raise the water from the level at which we discharge it from our tailraces up again into the mountains, by the age-old action of cloud formation and subsequent rainfall. Nowadays, the enormous potential demand for electrical energy, consequent on increased standards of living (which appear to make insatiable demands for energy) has caused anxious examination of the possible sources of future energy supplies. The hydro-power engineer has always played a vital part in providing for man's needs for energy, but he, being a realist, has always recognised that you can only harness water power where it exists, and you cannot create a hydro-electric scheme in a country the topography of which is uniformly flat and in which the rivers incline gently and sluggishly to the sea. Engineers who have been concerned with thermal power generation have developed their stations to perhaps the highest degree of efficiency they can ever hope for, and even the prevailing figure of about 40 per cent. is a sad reflection on man's inability to utilise more than just over a third of the latent energy in the exhaustible supplies of fossil fuels which he painfully brings to the furnaces of his power stations. To many who think only of the next 25 or 50 years, the future seems to be reasonably secure in the hope that atomic energy will come to the rescue. But if we look farther ahead we cannot help but be reminded of the prophetic words of Sir Harry Railing, the brilliant engineer, scientist and administrator, when he said at the British Electrical Power Convention in 1955 that even atomic power could not supply world demands in 50 to 100 years' time. Then, he said, it would be necessary that about 4 per cent. of the solar energy falling on the land surface of the earth should be converted for man's use at an efficiency of about 10 per cent; otherwise, we could not survive on the present basis of complete dependence on ample supplies of electrical power. For many years past in most industrial countries a small group of scientists has kept its "weather eye," so to speak, on the sun as a source of energy, and slowly, but apparently fairly surely, methods are emerging for more certain utilisation of solar energy at greater efficiencies. Two international conferences have been held, in 1953 and 1955, in Arizona, U.S.A., and at the latter event 700 scientists from 30 countries were present. It was pointed out that, at present, energy from the sun costs a great deal more than energy from conventional sources, but this is understandable in the early stages of harnessing solar energy, because exactly the same statements were made no more than five to seven years ago about atomic power, and yet atomic power is now predicted to be on level terms, economically speaking, with power from coal-fired stations.

One of the major problems that solar-energy pioneers have to face is that of storage. Many ingenious approaches have been made towards a solution of the problem of storing heat when available from the sun at such temperatures and by such methods that it can be released at any time for direct heating or for power generation. Chemical methods are being developed with some success, but there are many years of research yet to be carried out before really large-scale solar-energy plants will have reached the economic stage. One thing, however, is certain. The ideal partner for a solar-energy power station will be a hydro-electric station. This is because only the hydro-electric method of power generation offers any possibility at all of storage. The hydro station, if of the normal straightforward kind, could be so arranged that on the availability of solar energy the water power plant would be shut down, conserving the water in the reservoirs for use when the sun went in; or alternatively pumped-storage schemes could be developed on a very much larger scale than is contemplated even at the present time. Where the topography of the

country appears unsuitable, the overriding need for power might well make it economic to build vast civil-engineering works which would, perhaps, not only benefit the power engineers by providing pumped-storage reservoirs, but would also be of service in regard to flood control—a problem frequently encountered in flat countries—and also irrigation for the increased food production inseparable from a higher standard of living. In these columns, mention has been made on a previous occasion of the need for hydro stations, with their great flexibility, to act as partners to atomic power stations, where the peculiar conditions in the reactor vessels, with their huge heat inertia, preclude rapid starting up and shutting down, and thus demand high load factors. There is little doubt that solar energy will be developed, even though the path towards the direct harnessing of the sun's rays be long and arduous. There is even less doubt that when these problems are solved the faithful hydro-power stations which have served their communities for so long will still be needed and indeed will play a part of even greater importance.

British Aid to Launch Indian Heavy Electrical Industry

THE Indian Government has signed an agreement with Associated Electrical Industries Limited—the British group of companies headed by Metropolitan-Vickers Electrical Co. Ltd. and the British Thomson-Houston Co. Ltd.—to act as consultants in the creation of a heavy electrical industry in India. The appointment is for a basic period of 15 years. It has been secured in the face of keen competition from Germany and the United States, and will have the effect of establishing British standards and of securing substantial orders for factory plant to British manufacturers for a number of years.

A factory or factories will be established at an estimated cost of £20 million, employing about 10,000 people. The organisation will incorporate an apprenticeship scheme, but in the meantime many Indian nationals will receive training in A.E.I. works in England. A resident engineer and technical specialists will be furnished by the group, and a survey is shortly to be made of suitable factory sites.

It is the intention of the Indian Government to build up a heavy industry catering for their country's needs in hydro-electric plant, generators, transformers, switchgear, transmission equipment, electric traction and so forth.

Electricity in Rural Uganda

THE benefits of the Owen Falls hydro-electric scheme are now to be extended to the rural areas of Uganda, as electricity is to be made available over a wide area of Busoga, in the Eastern Province of Uganda. The Busoga electricity scheme will start at Jinja within a short distance of Owen Falls, and will stretch for many miles into the cotton-growing area of Busoga. Supplies of electricity will be made available to cotton ginneries, maize mills and oil mills, to coffee factories, small industries and hospitals, and to headquarters of the Local Government. Well over 1,000 premises in Busoga will benefit by the supply of electricity in the first few years after supplies have been given, and many more in later years. The scheme, which is estimated to cost £350,000, will require the construction of about 185 miles of high-voltage lines and will take over five years to complete.

The Uganda Electricity Board intends that this scheme shall be the forerunner of a number of comprehensive schemes for the distribution of electricity as widely as possible throughout Uganda.

Mexican Power Development Finances

DIRECTORS and officials of the Mexican Light and Power Company came to Mexico City from the U.S., Belgium and Canada at the end of October for a series of conferences with its Mexican representatives about long-term expansion plans. The Chairman of the Board of the Mexican Power and Light Company, Mr. Draper, announced that they would discuss the company's recent progress and plans for its 2,500-million peso expansion programme required to duplicate its facilities within the next ten years so that it could keep pace with the rapidly growing demand for light and power. The company made 1·9 million dollars profit on its Mexican operations in the first six months of 1955.

In San Francisco the Chairman of the Board of the Mexican Power and Light Company announced at a Press conference that the company would need some 200 million dollars in the course of the expansion programme and would look for financing outside of Mexico within the next few years. He added that the company had an application pending with the International Bank for Reconstruction and Development for a 10 million dollar loan, and also plans to raise as much money in Mexico as the capital market would permit.

Caroni Scheme Report

THE first hydro-electric station in Venezuela will be ready for operation by the end of 1957, it was recently stated by Major R. A. Ravard, who is in charge of studies for the scheme. Utilising the Caroni River in the State of Bolivar, it will have an output of 150 MW, the completed cost being estimated to be in the neighbourhood of 36 million dollars. It is probable that further plant will be added later, as the hydraulic potential of the river is considered to be greatly in excess of this capacity. The first batch of power produced will be used in the proposed steel and aluminium industries in Regio.

British Transformer Orders for U.S.

FOR the first time, the Tennessee Valley Authority has placed an order with the English Electric Export and Trading Co. Ltd., the contract being for four 40 MVA single-phase transformers for Wilson Dam, Alabama. The transformers will be built at Stafford. Tenders were received from six American as well as Austrian, Italian and British firms. The English Electric's price of $450,000 was $350,000 below the lowest American bid.

The same company has also been awarded a contract by the United States Corps of Engineers for a 90,750/121,000 kVA 13·2/161 kV 60 cycle transfor-

mer for Table Rock, for which the company is supplying two 68,000 h.p. Francis turbines.

Other transformer orders from the U.S.A. include those for the St. Lawrence power project—120 MVA, 230 kV; City of Seattle—125 MVA, 230 kV; Chief Joseph dam—310 MVA, 230 kV; Bonneville Power Administration—250 MVA, 254 kV, and the Folsom dam in California—80 MVA, 230 kV.

Loan to Uruguay

THE World Bank has granted a loan to Uruguay, amounting to 5 million dollars, to facilitate the development of the power potentialities of the country. This loan will be paid out in various currencies, among them Swiss francs, and will be used to purchase a turbo-generator manufactured by Brown, Boveri et Cie S.A., of Switzerland, and which is intended for the Battle plant, near Montevideo. The World Bank has also made a loan of 27 million dollars to assist in financing the construction of a power and irrigation project on the Litani River in the Lebanon.

British Nuclear Energy Conference

THE British Nuclear Energy Conference, which has been formed jointly by the Institutions of Civil, Mechanical, Electrical, and Chemical Engineers and by the Institute of Physics, held its inaugural meeting on November 30.

Sir Christopher Hinton, Managing Director of the Industrial Group of the United Kingdom Atomic Energy Authority, and Chairman of the Conference, said that in ten years nuclear engineering had so developed that it was an important industry in its own right and by 1975 would involve business in the home market amounting to some £300 million a year. The Conference was a collaborating and co-ordinating, rather than a controlling, body, its main objects being to assist in obtaining papers on subjects related to nuclear energy; to arrange for the printing and publishing of these papers in the *Journal of the British Nuclear Energy Conference*, the first issue of which would appear in January, 1956; and to promote meetings, symposia or conferences on a national or an international basis for the discussion of nuclear energy problems. Four lectures were delivered at the meeting by leading British authorities.

Hydro Power and Fish

THE North of Scotland Hydro-Electric Board has refuted a recent contention by Scottish anglers that hydro-electric schemes have adversely affected fishing prospects and, in particular, the claim that smolts are prevented from regaining the sea.

The anglers' view is that despite the use of ingenious fish ladders to allow upstream passage, there is no evidence that the smolts return safely to the sea. The compensation from the hatcheries also remains to be proved in the opinion of the critics, who suggest that the reduced numbers of fish returning to the sea will result in a decreasing inland run and ultimately damage the value of the rivers.

The Board has replied to these comments that their fish passes and inspection points are open to view by any interested party; that check netting of the exit areas had shown the presence of smolts; and that the existence in the rivers of young salmon makes it clear that these fish did pass down as smolts and have returned to their rivers as mature fish, thus proving the cycle to be completed, despite the introduction of the barriers necessary for power generation.

Our New Offices

On Monday, November 21, the Minister of Transport, the Rt. Hon. John Boyd-Carpenter, opened a new extension to the offices of Tothill Press Limited, the company owning and publishing this journal. The new building, which is at the rear of the present offices, is on the site chosen by Caxton to set up his printing press in the fifteenth century. It is in six floors, in contemporary style, and will increase the company's office accommodation by 150 per cent. The architects for the new building were Messrs. Yates, Cook & Darbyshire, and the main contractors Holland & Hannen and Cubitts Limited.

The publishing house now known as Tothill Press Limited was founded by the late Mr. J. A. Kay in 1910 under the name of Transport (1910) Limited, when he acquired *The Railway Gazette*, a weekly journal for which he had formerly worked as assistant editor under its earlier title of *Transport*. In 1913 a new weekly, *Shipbuilding & Shipping Record* was produced, and by 1920 the popular monthly *The Railway Magazine* and the accepted directories of the railway and shipping worlds had been acquired.

In 1918, with the purchase of *The Power User* (now *Power and Works Engineering*), a new policy was initiated of publishing a range of monthly technical journals covering the basic industries, and no less than ten such journals, most of them inaugurated by the company, are now published covering power production, gas and coke-oven practice, coalmining, mineral mining, quarrying, chemical engineering, building, timber, and food manufacture.

In 1931 Mr. Kay initiated a new type of journal *The Crown Colonist*, expanded after the last war to cover the whole of the British Commonwealth under its present title *The New Commonwealth*, appearing twice a month.

The idea to publish a journal devoted exclusively to hydro-electric practice was conceived before the war, but, like many other good ideas, had to be put into cold storage during hostilities. Publication commenced, however, in 1950, and in the six years of its existence, WATER POWER has built up a world circulation in all countries where hydro-electric development is of any significance. The reception accorded to it has been most gratifying, and has abundantly justified the foresight of the company in venturing to publish a technical journal with so wide a geographical coverage. It is this policy of continued development that has caused the company to outgrow its accommodation, and the new premises afford sorely needed facilities for the proper discharge of the many tasks involved in technical publication.

Hiller helicopter used for earlier soundings

River Soundings by Helicopter

By kind permission of Dr. Otto Holden, Chief Engineer of the Hydro-Electric Power Commission of Ontario, we are able to publish an account of how a series of soundings were made in the Long Sault Rapids on the St. Lawrence River

THIS article is published under somewhat unusual circumstances. A reference made in our June, 1955, issue to the use of helicopters for making soundings in the St. Lawrence Seaway attracted the attention of Monsieur A. de Tiesenhausen, one of the engineers in charge of hydro-electric developments in the Belgian Congo, who wrote to us for further information. His inquiry was duly forwarded to Dr Holden who replied very fully indeed and subsequently acceded to our request to publish the information in this journal. Having given this explanation we now proceed to give the substance of Dr. Holden's letter.

Reasons for Using Helicopters

Normally, soundings operations are carried out using either a boat or an overhead cable technique In special cases, in fairly fast or turbulent water across wide stretches, kytoons have been used. If, however, the current is very fast, the sounding weight required to overcome the force of the current is too heavy to be carried by kytoons, and also the operation is sometimes severely handicapped by unfavourable wind conditions.

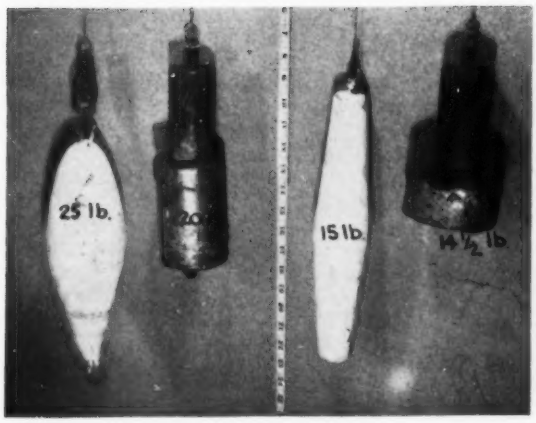
In our sounding of the Long Sault Rapids of the St. Lawrence river, we were faced with the problem of a wide stretch of very fast, turbulent waters. It proved to be impossible to get a boat into this section. the width of river was much too great to permit use of overhead cables, and the speed of the water ruled out the possibility of using kytoons. The helicopter method was therefore the only method by which we could obtain soundings.

Methods of Using Helicopters

The method employed in this type of sounding is to suspend a lead weight by fine music wire from the helicopter. At a known distance above the bottom of the lead weight a target flag is fixed. The upper portion of the music wire passes over a free-running drum

Right: R.C.A.F. helicopter taking off with sounding weight on the ground

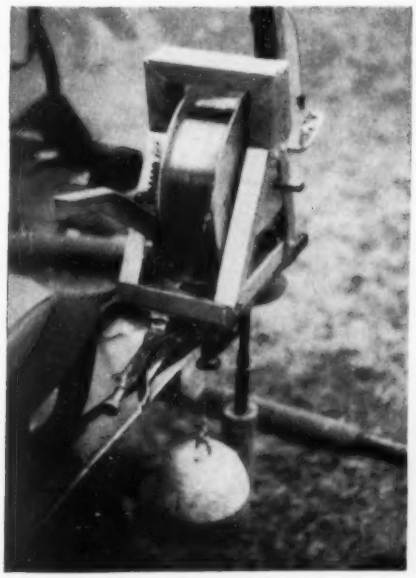
Below: Installation on Bell helicopter showing earlier types of weights used



Above: Latest sounding weights and counterweights

Right: Rear view of Hiller installation

Below: Radio control car in use



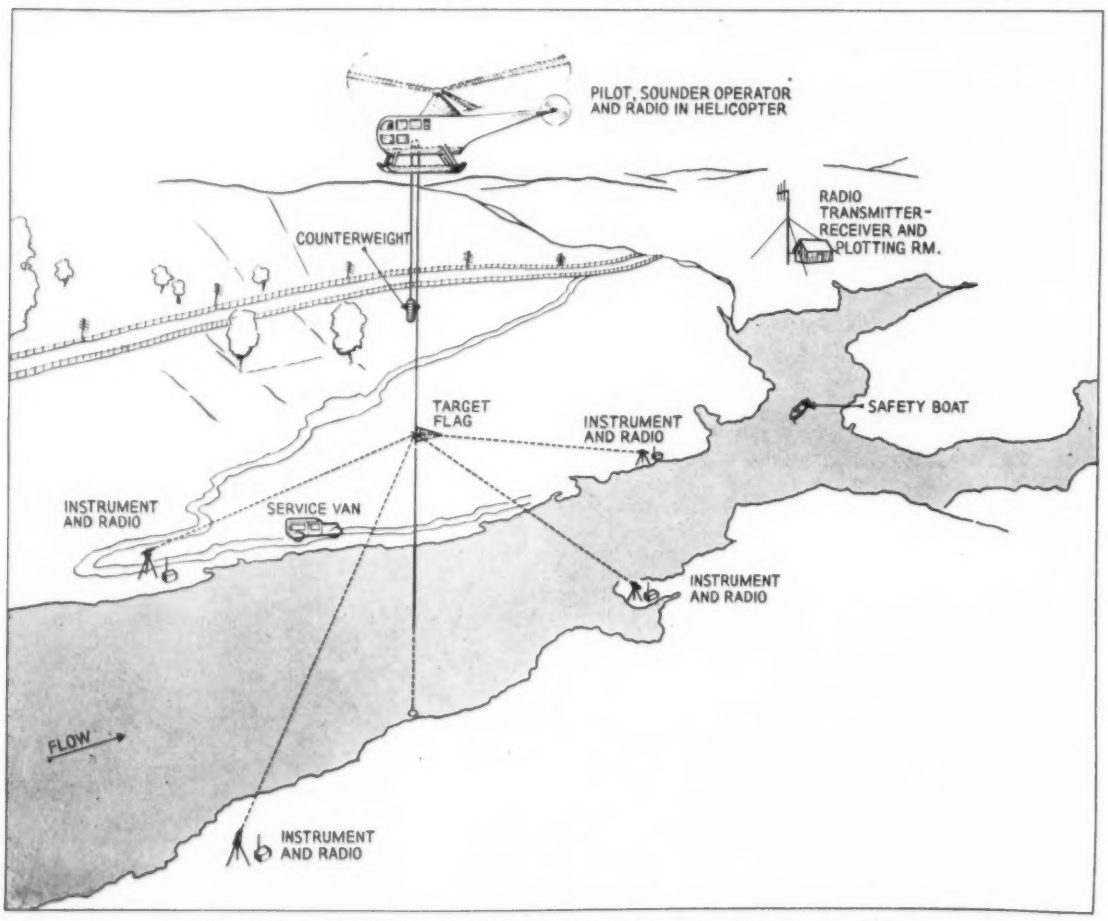
in the helicopter and continues in a downward direction to a counterweight, not as heavy as the sounding weight, which is attached to the end. This counterweight is connected to the main portion of the sounding line by a guide ring. When the sounding weight is hanging free in the air, the counterweight is drawn up against the drum in the helicopter. To obtain a sounding, the helicopter is lowered and the sounding weight plunges into the water and comes to rest on the river bed. The effective force being thus removed from the sounding wire, the counterweight is free to fall away from the drum, and thus acts to maintain tension in the sounding wire. By this means, the target flag on the sounding wire is held vertically over the spot on which the sounding weight is resting. Should the weight have been pulled, or drifted, downstream, the helicopter is manoeuvred to plumb itself over the weight. When everything is ready, a radio command is given by the person co-ordinating the operation, and several transits, located at co-ordinated points of known elevation, read the horizontal and vertical angles to the target on the sounding wire, thus fixing its horizontal and vertical position by intersection; then, by application of the known distance from the target flag to the bottom of the sounding weight, the elevation of the river bed is obtained. The operating height of the helicopter is dictated by safety considerations (accessibility to emergency landing fields, etc.). Our operations were flown at 1,000 ft.

Model of Helicopter Used

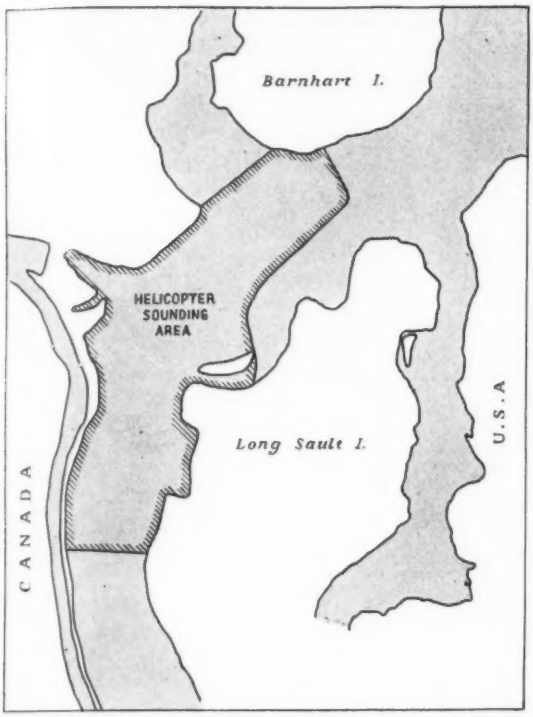
The first soundings were made using a 200 h.p. Hiller helicopter. This type of helicopter required a minimum wind velocity of 12 miles per hour in order to hover and perform the necessary vertical movements. The sounding weight that was used from this small helicopter proved to be too light for the deep, fast-flowing sections of the river, and a heavier weight necessitated an increase in the minimum operational wind velocity. It was necessary, therefore, to make use of a heavier, more powerful machine, and the Royal Canadian Air Force provided a Sikorski S-51, with crew. This heavier machine proved to have sufficient power to enable it to operate in very light breezes; it was found also that still heavier equipment could be used, thus permitting the sounding of otherwise inaccessible areas of water.

Difficulties Encountered

The initial difficulty was the snagging of the sounding weight on rocky knobs or in crevices in the river bottom; this meant that the sounding line broke and the lead sounding weight was lost. When this occurred the helicopter had to return to shore, land and re-rig



Perspective sketch showing how the helicopter soundings were taken



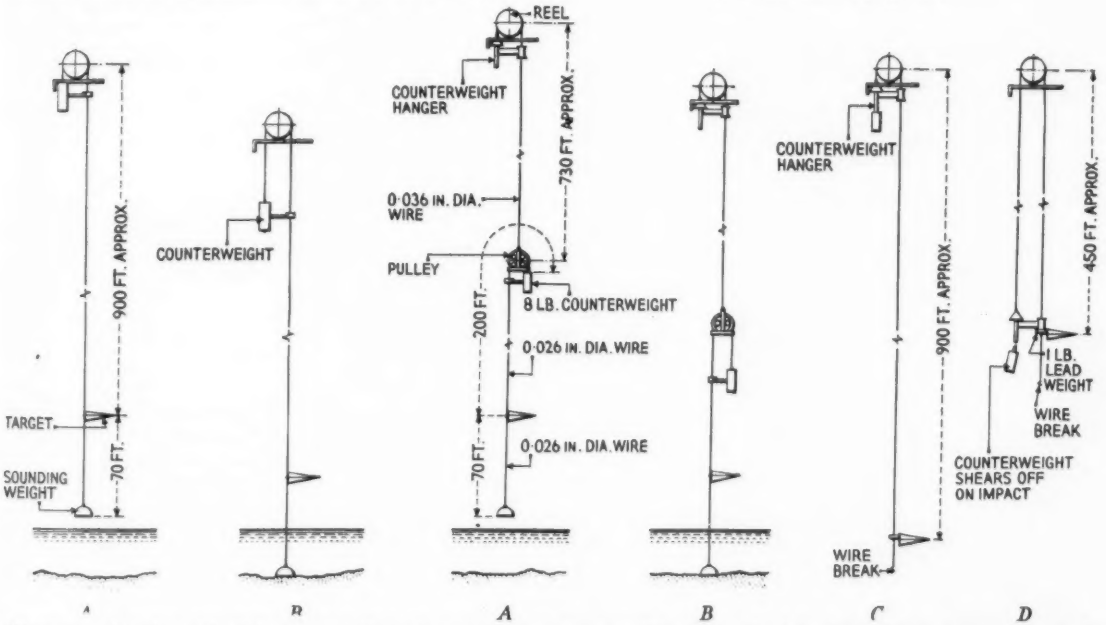
Map of St. Lawrence River showing the helicopter sounding area. The remaining areas shown were charted by echo sounding

new sounding equipment, take off again and return to the scene of operations. In terms of money and time, this procedure was very expensive; there was also a dangerous aspect to it as on two occasions the breaking of the sounding line under tension caused it to spring up into the rotor blades necessitating emergency landings and costly repairs to the helicopter. Three steps were taken to overcome this difficulty: (a) the shape of the sounding weight was changed from the original "button-shape" through spherical and hemispherical to the finally adopted tear-drop shape; (b) the sounding line was modified to make a weak link of that section below the target (0·26 in. wire), the remainder of the sounding line through to the counterweight being of 0·35 in. diameter wire; (c) the counterweight was redesigned to enable it to jam on the sounding line in the event of a break, thus preventing the free end of the sounding line from springing up into the aircraft.

The second difficulty was that in deep, fast-flowing sections, the resistance of the sounding line caused a drag which depressed the target flag in a manner to cause erroneous results. This problem was solved by using heavier equipment with the Sikorski S-51.

One other major problem was the tendency of the counterweight to swing around the sounding line and carry the counterweight section of wire with it. It was sometimes possible to correct this situation by manually unwinding the twist, but on other occasions it was necessary to cut the wire, thus often losing all the connected equipment. No really satisfactory method of overcoming this difficulty was devised before the sounding operations were concluded but it was found to be very helpful to have the counterweight on the forward or windward side of the sounding line and minimise the length of the link connecting the counterweight to the sounding wire. Conflicting wind and river currents will however still cause difficulties.

(Continued on page 24)



Diagrams showing principle of operation of sounding equipment. Those on the left show direct suspension and those in the centre, remote pulley suspension; diagrams A *show sounding weight suspended and* B *sounding weight on river bed. Diagram* C *shows safeguard against a wire breakage when counterweight is locked up, and* D *when counterweight is free*

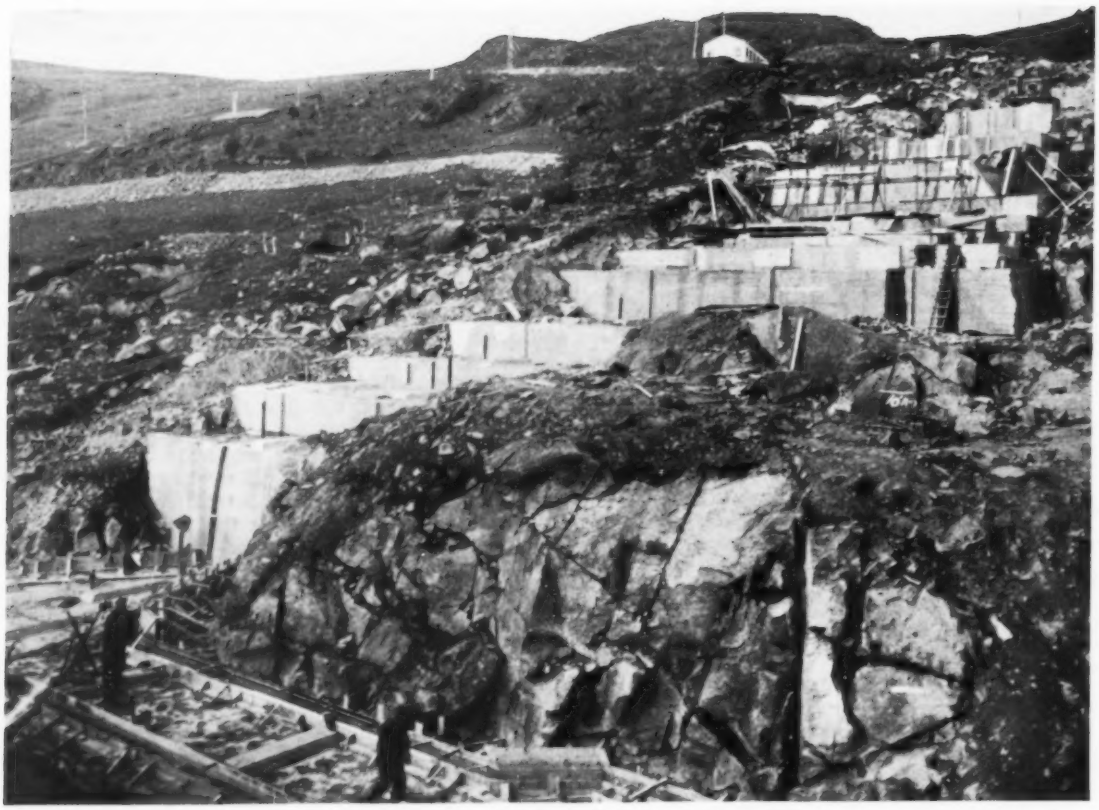


Fig. 1. Foundations of east gravity section of Lednock dam

High-Speed Tunnelling Techniques

A world tunnelling record was recently established in a heading being driven by the Mitchell Construction Company for the North of Scotland Hydro-Electric Board's Breadalbane scheme. A mining engineer of our staff describes the methods of driving employed on this civil-engineering contract and assesses the factors that contributed to this achievement

WITHIN the last year, there have been a number of references in this journal to tunnelling records that have been established during work for hydro-electric schemes in the North of Scotland. As there are some twenty projects currently under construction for the North of Scotland Hydro-Electric Board, a number of large civil-engineering contracting firms employing a total of around 9,000 men are engaged at numerous sites and a high degree of friendly rivalry exists between them. Roadmaking, laying of aqueducts, installation of dams and water intakes, and the driving of underground tunnels and shafts are being completed, in some cases, ahead of schedule. These results are all the more creditable when consideration is given to the inaccessibility of many of the schemes, particularly at their commencement, and to the existing communications, or lack of them. It is felt therefore that civil engineers will readily appreciate the difficulties of conducting underground work under conditions prevailing in the Highlands and be particularly interested in the tunnelling techniques that have led to the spectacular advances which culminated in the establishment of a world record of 557 ft. of 8½ ft. × 8½ ft. tunnel in seven working days.

At the present time about 15 per cent. of the potential water power of the Highlands has been harnessed and about a further 40 per cent. is under construction and survey. Some 23 hydro stations are in operation

with a total capacity of 525,885 kW and there are a further 20 hydro power stations under construction. Seven schemes are undergoing survey.

One of the larger projects on which civil-engineering works are now proceeding is the Breadalbane scheme in Perthshire, where, with the Lawers scheme which has just gone into operation, there will eventually be eight power stations with a total capacity of 121,500 kW.

The Breadalbane scheme is made up of three sections which collect and utilise water from an overall catchment area 25 by 15 miles lying approximately north-west and south-west of Loch Tay. The most southerly of these is the St. Fillans section which involves the construction of two main dams and three generating stations. One of the contractors responsible for civil-engineering work on this scheme is The Mitchell Construction Company of Peterborough, who have established a camp and administrative headquarters at Comrie with facilities and accommodation for 500 men.

This firm has approximately 19 miles of tunnel of different sizes to drive in connection with their part of the St. Fillans scheme, as well as some 12 shafts ranging in depth from 20 to 600 ft. and from 10 to 25 ft. in diameter. During recent months tunnelling progress has been maintained at a rate of just over 1 mile per month, and any necessary lining with concrete will be done at a later date. In general, the feeder tunnels are lined for only the invert, whereas the pressure tunnels are fully lined.

St. Fillans Scheme

An outline of this section of the Breadalbane hydro-electric project will clarify the purpose for which the underground work is required, and Fig. 2 shows that part of the scheme with which Mitchells are directly concerned. Their contracts cover the construction of two generating stations, the one at St. Fillans having a capacity of 21 MW and that at Dalchonzie 3·5 MW, as well as the arrangements for collecting and delivering the water to them. The consulting engineers for the scheme are Sir Murdoch MacDonald and Partners for the civil-engineering side of the work, and Messrs. Kennedy and Donkin for the electrical.

There are three parts to this scheme, these being known as the Almond, St. Fillans and Dalchonzie sections. When considering the scheme as a whole, it is logical to start at the most northerly of these sections and trace the flow of water through to its eventual discharge into the River Earn, involving an overall difference in elevation of 1,100 ft.

The Almond section of the work consists of arranging for the collection of water from the River Almond and its tributaries. This is directed by four major, and

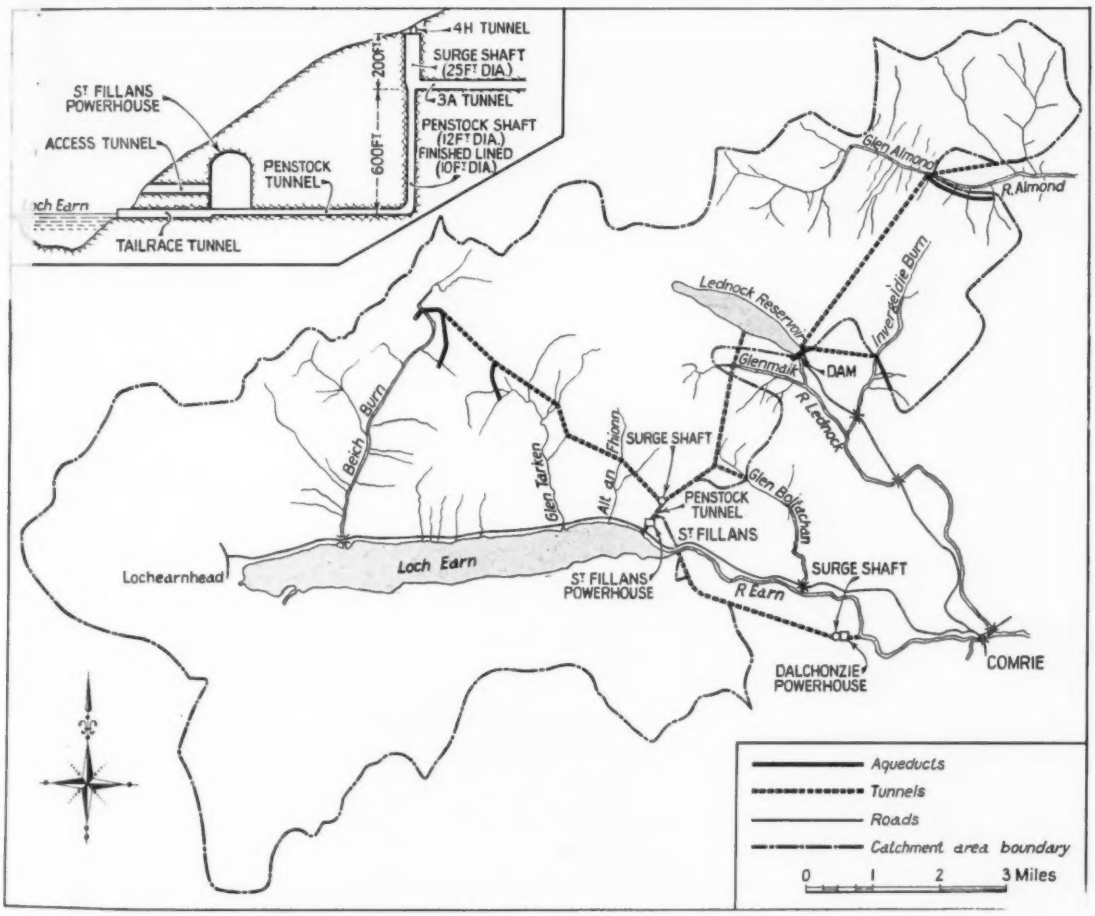


Fig. 2. Map of Breadalbane scheme, with inset profile of station and surge shaft

numerous smaller, intakes into some 2 miles of precast concrete aqueduct and 5½ miles of tunnels, through which it is led to the storage reservoir to be formed at Lednock. It was in this Lednock-Almond tunnel, the 10A which was cut to 10 ft. bed width*, that a British and European record rate of advance was achieved early last year when 428 ft. were driven in seven working days.

A dam is in the course of erection at Spout Rolla on the River Lednock to the south-west of the outfall of the Almond tunnel, this contract being entrusted to Taylor Woodrow Construction Limited. This dam will be a diamond-headed buttress structure 900 ft. long and 120 ft. high. As will be seen from the plan of the scheme, the reservoir so formed will provide storage for the waters emanating from the Almond catchment area as well as collecting the major proportion of the flow of the River Lednock. In addition water is to be drawn from the area to the west of the Lednock reservoir, this again necessitating aqueducts and a feeder tunnel.

The St. Fillans section of the scheme contains underground work of the greatest interest. Water from the Lednock reservoir is passed through the 3A tunnel, 3½ miles in length lined to a diameter of 9 ft. 6 in., to a point underground at the bottom of the surge shaft. Water from two areas lying between Lednock and St. Fillans is coursed into this tunnel through connecting aqueducts and tunnels.

Into the top of the surge shaft will come water collected from the most westerly parts of the catchment area. This water, together with that from Glens Beich and Tarken, will be diverted for power generation at the St. Fillans station. Although the original layout for this part of the scheme called for a series of short tunnels and aqueducts, it has now been decided to drive an 8 ft. 6 in. bed-width feeder tunnel for the whole distance of 4¼ miles and supply it from aqueducts as indicated in Fig. 2. The recent seven-day world tunnelling record was set up in this particular tunnel, in that section being driven from the portal beside the top of the surge shaft.

The surge shaft is a vertical excavation 200 ft. deep and 25 ft. in diameter, below which is a vertical penstock shaft. This will be concrete-lined to a diameter of 10 ft. for its whole depth of 600 ft.; it is to be cut to 12 ft. in diameter employing a relatively new type of raising technique for this type of contract.

From the top of the shaft, a 5 in. cored diamond drill hole has been put down vertically the full depth of the shaft, to the elevation of the penstock tunnel through which access will be obtained. This hole was drilled by the Craelius Co. Ltd. and progress surveying for checking on deviation was done by passing a small camera down the hole and photographing a plumb-bob. From an electrically-powered winch mounted at the top a cable will be passed through the hole, and a platform or container made fast to it. This will be raised up to the face for the drilling and charging operations, VHF radio communication being used to maintain control. Holman Dryductor drilling machines are to be employed for drilling off the round, the cable hole being used for the cut, and the dust collected will find a use in stemming. After loading the holes, the "cage" will be lowered, disconnected from its rope, and stowed in a recess cut for it at the bottom of the shaft. After blasting, which will be done with Cordtex in preference to electric detonator, drilling operations may be resumed rapidly, while the muckpile below is cleared by an Eimco 21 rockershovel. It is anticipated confidently by the management that this method will permit a greatly increased speed of advance for this shaft.

* "Bed width" refers to the width of the tunnel at its base; the maximum height from rail to the top of the arch of the tunnel is, for all practical purposes, the same as its width.

Fig. 3. Tunnels from Glen Almond and Invergeldie to Lednock

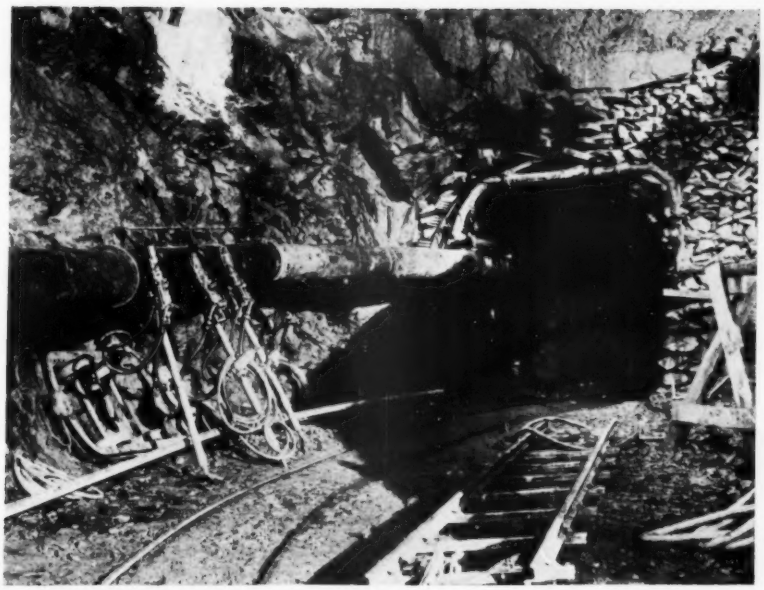


Fig. 4. Portal of 7 ft. 6 in. tunnel now being driven eastward from Glen Almond to pick up water from north tributaries

Fig. 5. View of the Glen Almond portal of the completed three-mile tunnel from Glen Almond to Lednock

Water from the penstock tunnel, now having a head of 800 ft., is taken to the turbines through the penstock tunnel, steel lined to a diameter of 8 ft. So that the natural amenities of the district are preserved, the St. Fillans generating station is located underground inside the hill on the banks of Loch Earn; it has been excavated 75 ft. long by 50 ft. wide to a height of 75 ft. from the concreted ceiling to the base of the penstock tunnel. On the occasion of our visit, mucking was in progress in this station and the broken rock was being loaded by an NCK model 304 ¾ cu. yard face shovel into Aveling-Barford 4½ cu. yard diesel dumpers.

From the turbines the water will be discharged through a short tailrace tunnel running below the Lochearnhead-Comrie road into Loch Earn.

The Dalchonzie section utilises the water discharged from the St. Fillans generating station together with the run-off from the natural catchment of Loch Earn. Near the outlet of the loch, a diversion dam is being built. Water will be directed to the tunnel intake and into a 3½-mile concrete-lined 11 ft. 6 in. diameter tunnel. This feeds a surge shaft and the Dalchonzie generating station, after which the discharge is diverted back into the River Earn some 4½ miles downstream from St. Fillans. At the intake screens have been provided to prevent fish passing into the tunnel, and a fish pass is incorporated to allow the passage of migratory fish.

From the brief description given above of the whole scheme, it will be noted that the tunnelling side of the work represents a major part of the construction. Bearing in mind that the weekly footage averaged in each of the headings driven on the whole scheme to date has been 200 ft., it will be seen that the factors contributing to this rapid advance are worthy of closer study.

Tunnelling Technique

The description that follows concerns itself primarily with the methods that were adopted in driving the tunnel where the record-breaking 557 ft. advance was established in seven working days. This was obtained with conventional equipment, which, with the exception of the drill steel, was all of British manufacture and similar to that used on all the tunnels of the scheme. Also the make-up of the crews and the technique adopted showed no departure from normal practice in other tunnels on this contract. The 4H tunnel was cut through an epidiorite rock comprising a hard grit with mica intrusions known locally as Ben Ledi grit.

The tunnel was driven on three eight-hour shifts throughout the 24 hours, and each crew was made up of one shift boss, five drillers, one handyman, one compressor man, one loader operator, two loco drivers, two men on the rock tip, and one electrician. The services of a fitter, drill doctor and powder monkey were available on day shift only. All shifts

Fig. 6. Surge-shaft portal of the tunnel in which the record was secured

came under the direction of a tunnel foreman, in this case Mr. Norman Bromley.

Starting with the drilling operation, an average of 22 holes 8 ft. deep was drilled per round. At the face in this $8\frac{1}{2} \times 8\frac{1}{2}$ ft. heading were the five drillers, the handyman and shift boss. Each driller used a Holman Silver Three Handril mounted on an airleg and was responsible for drilling four or five holes, dependent on the ground encountered, per round. The Silver Three is said by Holman Brothers Limited to be the fastest machine in their range of pneumatic rock drills, designed especially for use with airlegs and tungsten-carbide-tipped steels. It is classified as a medium light-weight drill and is characterised by using a relatively light blow with a high piston speed. The bore is 3 in., the stroke is $1\frac{5}{16}$ in., and the wet-drilling version weighs 49 lb.

These drills were used with Sandvik Coromant tungsten-carbide-insert steels of the chisel-bit type with a diameter of 39 mm. Only one change of steel was necessary per hole, a 5 ft. length being used as a starter followed up by an 8 ft. An average life of 800 ft. per drill steel was obtained and each steel was dressed after very round (or approximately 40 ft.) on an Atlas Diesel sharpening machine sited at the tunnel portal.

One of the functions of the handyman during the drilling part of the cycle was to change steels for the drillers, and hold the starters during collaring. After driving the 5 ft. steel on one hole, the drill was moved to the next hole which was collared and drilled to its initial depth of 5 ft. During this period, the previous 5 ft. steel was changed ready for completing that hole, and the drill could then be moved on to the 8 ft. without stopping the machine. The shift boss stood behind the five drillers and paid particular attention to the feet of the airlegs, especially when the bottom holes in the face were being drilled. The burn cut was favoured, five parallel holes being drilled of which the centre one was not charged. These holes were drilled with the same steel used for the rest of the holes in the face.

To avoid having long lengths of $\frac{3}{4}$ in. air and $\frac{1}{2}$ in. water hose from the five machines curling about on the floor of the tunnel, the usual header arrangement

Fig. 7. An Eimco 21 rockershovel loading into a Hudson 40 cu. ft. car in one of the tunnels

Fig. 8. One of the 15 Ruston Mark LBU diesel locomotives operating on the scheme

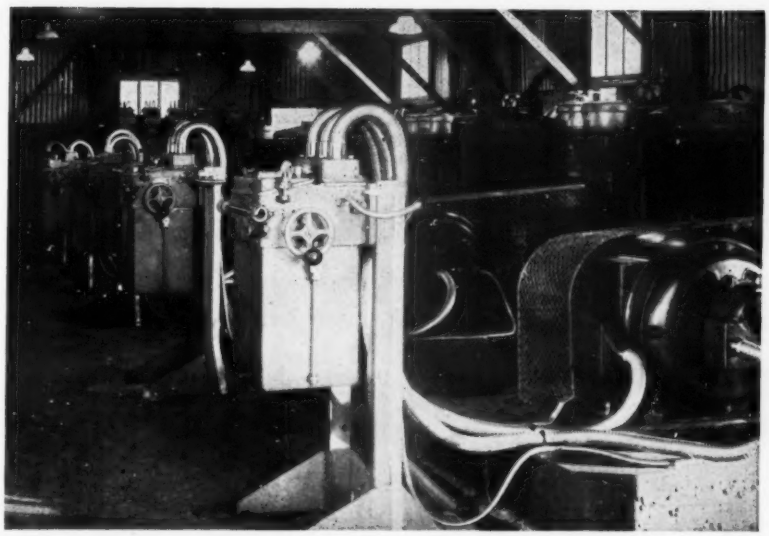


Fig. 9. Central compressor station containing five Holman T60R 535 cu. ft. per min. compressors

on the 4 in. air and 2 in. water pipelines was dispensed with. In its place were installed two flexible "bags" which brought these services close up to the face; from these bags, short hoses connected through quick couplers supplied the drills. When drilling was completed, the bags could be quickly removed with the rest of the drilling gear.

During the week under consideration, the drilling part of the cycle occupied an average of 25 min. during which time the rest of the crew were not idle, maintenance of the mucking and haulage equipment, track, and ventilation tubing and cleaning the tunnel and drain being some of their tasks while waiting. Explosive was brought into the tunnel and held ready at a safe distance back from the face, so that the minimum amount of delay occurred between the drilling and charging operations. Explosive was stored in a class D magazine, licensed for 4,000 lb., located some distance from the portal. Each tunnel site has one such store, replenished by the explosive suppliers.

On completion of the drill holes, the machines and gear were rapidly removed to a point some 500 ft. back from the face where it was arranged in an orderly fashion behind the Eimco loader. The upper assembly of this was turned at right angles to the track before blasting to create a shield for the rest of the equipment. Although each driller had a set quota of holes to put in, if he finished ahead of his neighbours because of differing ground or other conditions he would stay to assist with the completion of the round rather than remove his gear and take a rest. There is no room for a selfish attitude of mind on these contracts and under conditions where every minute saved is of vital importance. Also the men themselves will not suffer such an individual in their team.

After stowing the drilling gear, the shift boss returned to charge the face. About 70 lb. of 1⅛ in. Polar Ammon Gelignite, supplied by the Nobel Division of Imperial Chemical Industries Limited, was used in each round and used in conjunction with electric detonators having delays from 0 to 7. The primer cartridges made up outside the tunnel, were placed at the bottom of the holes, which were then loaded solid to within a foot of the collars; two cartridges of sand stemming completed the charging, the lead wires connected up and the circuit made to the blasting cable that was strung along one wall of the tunnel. From the firing point approximately 1,000 ft. back from the face, the circuit was tested for continuity by galvanometer and fired. The operation of charging and firing a round of shots averaged 10 min. per cycle.

This aspect of the cycle received particularly close attention from the supervisor who had to ensure that no short-cuts were taken that would lead to unsafe practice. This was achieved, to the credit of the management, without creating among the men any frustrating feeling that they were being held back in their attempt on the record. Some 88 rounds were blasted during the week, consuming 6,300 lb. of explosive, and the average pull per round was 6 ft. 4 in.

On the average, a period of 17 minutes was allowed for clearing smoke after a blast. To provide auxiliary ventilation in the tunnel, a 15 in. steel pipe was installed along one wall. At the portal of the 4H tunnel. a paddle-bladed fan powered by two 7½ h.p. electric motors was connected to this and arranged to flow fresh air into the face. Approximately 1,500 ft. inside the tunnel a 15 in. Aerofoil axial-flow fan, made by Woods of Colchester, was installed as a booster.

On re-entry to the working face, any necessary barring down of the back and walls was done as the mucking equipment was brought forward. Two drills were then connected up and the upper holes of the

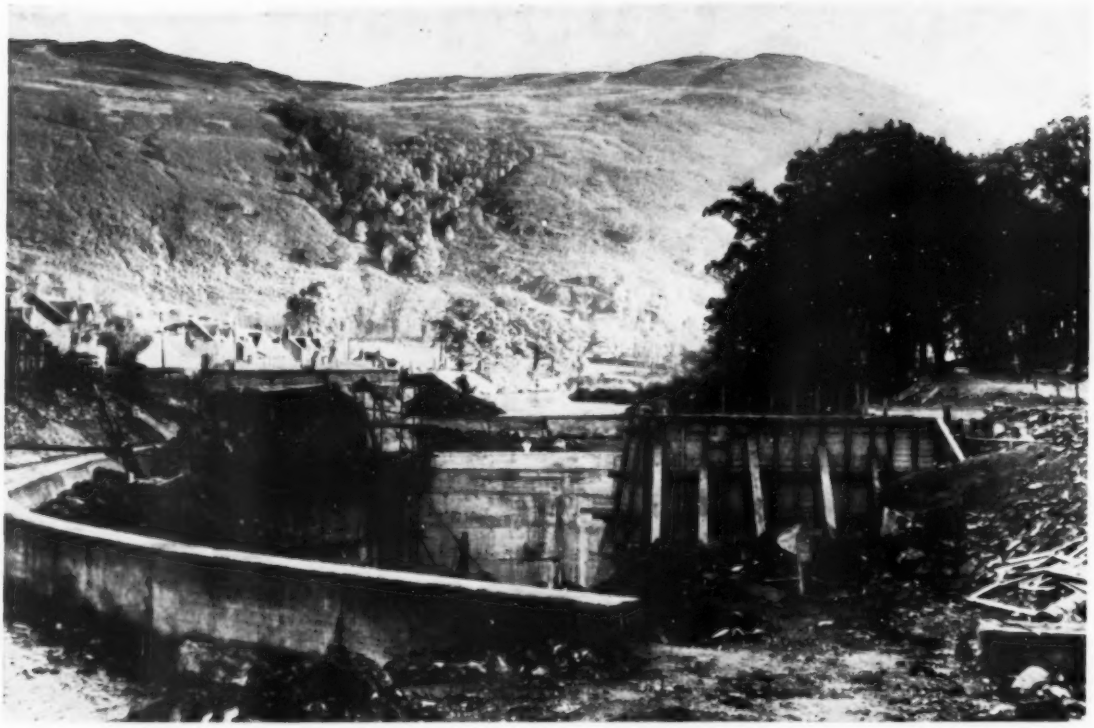


Fig. 10. Offtake from Loch Earn to Dalchonzie power station

next round drilled off from the top of the muckpile, while loading of the broken rock commenced with the cleaning up of the fly rock back from the face. These holes were completed and the drills removed by the time that the loader had advanced well into the muckpile, and thus the loading operations were not hindered. It was essential to the rapid advance that the pile of broken rock always assumed certain definite proportions; no undue scattering of the material, to any great distance back down the tunnel, could be permitted, neither was it desirable to have too high a muckpile immediately in front of the face. The ideal aimed at was a 3 ft. pile of broken rock extending back for some 15-20 ft.

Fig. 11. St. Fillans machine hall under construction showing part of the concreted roof arch

Mucking was done with an Eimco model 21 rockershovel, loading into 40 cu. ft. mine cars made by Robert Hudson Limited of Leeds. As this part of the cycle took one hour, the Eimco operator on each shift was a key member of the working crew and had to be highly proficient in the handling of his machine. Although at the start of the record-breaking week there was one such operator for each shift, one of the three fell sick during the early stages of the attempt. Rather than have a replacement driver introduced at this stage—and a highly trained man was available—the remaining crew members were unfavourably disposed to this substitution and for the remainder of the week the two remaining Eimco operators worked 12-hour shifts. This serves to emphasise the reliance that crew members had for each other and the fear that outsiders coming

into a shift might not be able to fulfil the necessary functions required of them.

For changing cars rapidly behind the face, a section of double track with switches at either end was provided which was laid on top of the normal 30 lb. 2 ft. gauge single track running in the tunnel. This unit was moved forward as required, and each of its tracks was long enough to accommodate four cars and a locomotive. Two locomotives were used, an electric storage-battery unit being used for shunting duties at the face and a diesel engine for main haulage of the trains to and from the disposal tip near the portal.

The battery locomotive was of the B.E.V. type W.227 manufactured by Wingrove and Rodgers Limited of Liverpool.

The diesel locomotive used was the mark LBU of Ruston and Hornsby Limited, of which there are fifteen engaged in similar duties throughout the various sites. This machine is fitted with a Ruston four-stroke cycle vertical diesel engine and has an exhaust conditioner making it suitable for operation in naked-flame underground locations.

Spoil from the tunnel was in this case tipped, but in most cases it has been utilised for making access roads; by the end of the scheme, this contractor will have provided some 30 miles of these. Before tunnelling operations could be started at any particular location in these glens, it was necessary to establish roads into the site. Wherever possible, use was made of broken rock produced in other tunnels, and the driving schedule was organised with this consideration in mind. The contractors have on this scheme a fleet of 25 Aveling-Barford 4½ cu. yard diesel dumpers, eight NCK model 304 ¾ cu. yard face shovels, and three Caterpillar D7 tractors fitted with bulldozing blades. This equipment is used for making the initial cut into the hillside, to the point where solid rock is encountered. This material is loaded, dumped and spread and site buildings established. Later, the rock from the tunnel is laid as a road to the next point at which entry for tunnelling may be required. These roads are laid 18 in. thick, with the coarser material as a base, and have proved to give a surface satisfactory for the vehicles using them. They have not, of course, been provided with a surface finish suitable for motorcar traffic, and the routes followed are somewhat precipitous. Over these roads the fleet of 13 Land Rovers gives a most impressive performance, and these useful vehicles have been proved to be eminently suitable for these conditions as carriers for personnel and light stores.

Services

Compressed air for the 4H tunnel was brought from a central compressor station located on the surface between the surge shaft and the St. Fillans generating station. It was sited here to ensure that no noise could be heard in the villages of the neighbourhood.

Here there are five Holman T60R 720 r.p.m. stationary compressors, delivering 535 cu. ft. per min. of free air at 100 lb. per sq. in. pressure, and powered by a Crompton Parkinson 120 h.p. electric motor. These

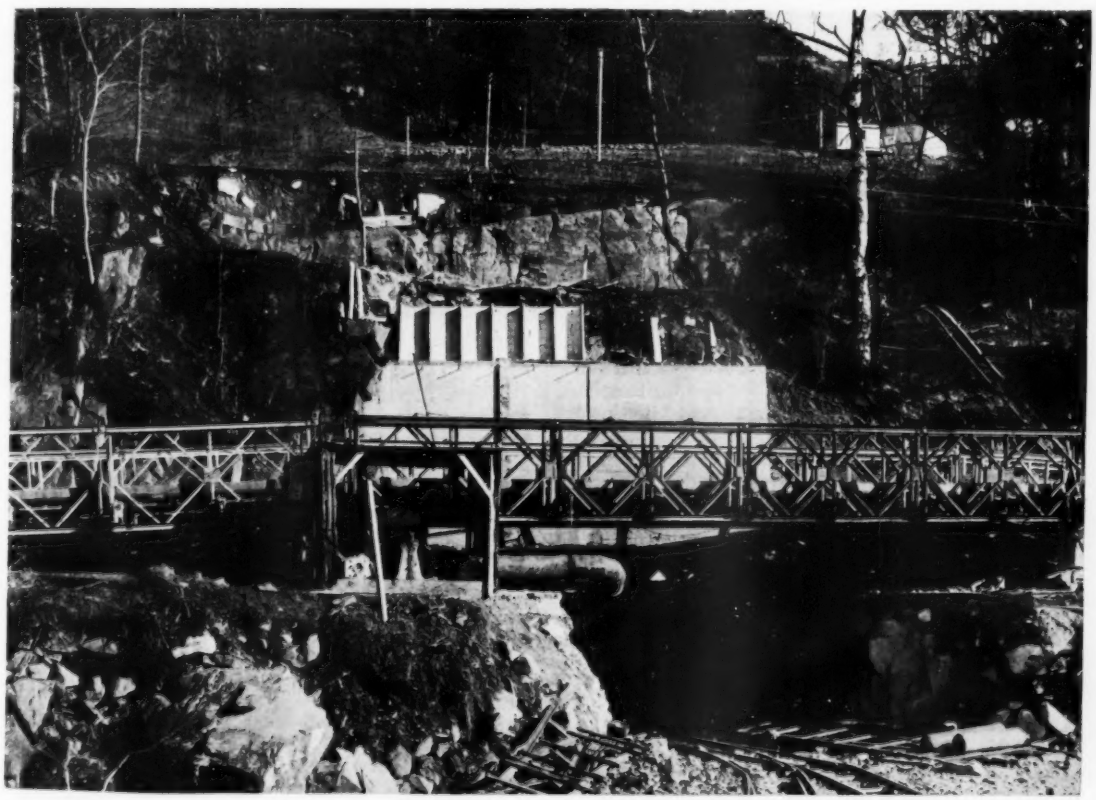


Fig. 12. St. Fillans tailrace portal and concrete securing wall

are two-stage units, cooling being achieved by a closed-circuit system of water cooling. The complete installation is of a semi-permanent nature, the machines set on concrete foundations in a spacious well-lit building erected especially for this purpose. Each compressor feeds a small air receiver, of approximately 75 cu. ft. capacity, and from these two mains are taken off, one of 6 in. diameter to the workings located below the station and a 4 in. diameter line to the upper sites (which include the 4H tunnel).

Electric power is supplied by the Board at 11 kV and transformed to 440 V for operating the motors driving such equipment as compressors and fans, and to 110 V for tunnel lighting. These lights are arranged at a set spacing along the supply cable, which is fixed to the air and water-line supports along one side of the tunnel. This cable may be extended quickly, to give adequate lighting at the face and throughout the length of the tunnel. As it is not deemed necessary, no auxiliary means of illumination is carried by the men, except for the shotfiring part of the cycle when acetylene lamps are used. This avoids bringing the lighting cable too near to the electric detonators, and it is removed well back from the face before charging operations commence.

In the foregoing description details have been given of the technique and machines used in the 4H tunnel. Significant as these factors undoubtedly were in contributing to an achievement of this type, of greater importance was the attitude of mind adopted by the crews. It is to the management in charge of the contract as a whole, as well as the tunnel driving in particular, that much of the credit for the record must go, in that the enthusiasm of the men to make the attempt was encouraged and retained until favourable conditions existed. It would have had a detrimental effect on the morale of all crews if any bid for the record had been made and failed.

Three conditions were required before the men were permitted to exert their maximum effort. Firstly, it was desirable that the tunnel face should be relatively close to the portal, so that haulage times for the broken rock could be kept to a minimum. At the same time, too "new" a tunnel would be unsuitable as the crews would not have had adequate time to settle down to the operating cycle. Secondly, the ground through which the tunnel was being cut had to be "pulling" well and offer satisfactory prospects for continuing to do so. And lastly, the members of the crews had to be working well together as a team and there had to be no passengers.

Acknowledgments

We are happy to record our indebtedness to the North of Scotland Hydro-Electric Board for permission to inspect the site and to the Mitchell Construction Company for enabling us to observe the tunnelling techniques in use. In particular, we wish to thank Mr. G. C. Cummings, Agent, and Mr. W. A. McClunie, Tunnels Manager, for their helpfulness over supplying the data from which this article was prepared. Also we wish to express our appreciation to Holman Brothers Limited for making the arrangements for our visit.

Escher Wyss: 150 Years of Development

The famous Swiss firm of Escher Wyss was founded in 1805 by Hans Caspar Escher and Salomon Wyss, and can claim a history going back to the very beginning of engineering in Switzerland. To mark its 150th anniversary the firm has very appropriately published a 246 page book under the above title telling the full story of the vital part it has played in the development of hydraulic and thermal power plant, compressors and blowers, and related equipment.

Originally the works were established as a mechanical spinning mill, with its own machine shops attached, and within a few years the company was building its own waterwheels and mechanical-transmission equipment and supplying waterwheels to clients. Steam engines and water turbines followed in the 1830s, but when the electrical transmission of energy became an accomplished fact, the development of both hydraulic and thermal power equipment received a new impetus, and the company soon established an international reputation.

The section of the jubilee publication devoted to hydraulic installations makes fascinating reading, and indeed is so replete that a detailed commentary would be difficult to write. Suffice it to say that it embraces a history commencing with the old-fashioned waterwheel followed by a 4 m. diameter Jonval runner developing only 40 h.p. to the 63,000 h.p. Francis turbines for Fionnay operating under a head of 460 m. —reputed to be the highest head for which Francis turbines have yet been built. In the field of hydraulic research, too, the book has most interesting matters to record.

Our comments on even the hydraulics section of this volume are admittedly incomplete, and when we take into account that the book deals equally well with the company's exploits in the development of steam turbines, closed-cycle air turbines, compressors and blowers, shipbuilding, refrigerating plant, boilers and other miscellaneous equipment, we can but record that this jubilee volume is a magnificent production.

St. Lawrence Research

According to the Quarterly Bulletin of the National Research Council of Canada, Mechanical Engineering Division, for the quarter ended September 30, 1955, routine testing continued on two large models of reaches of the St. Lawrence River. Verification of the Galop Island model was virtually complete and the model was being used to cross-check prototype data. The Cornwall Island model continued to be used for tests relating to the power development on the St. Lawrence. This model, which represents a 10-mile section of the river to a horizontal scale of 1 : 480 and a vertical scale of 1 : 96, has been revised many times to incorporate new design channels. It is expected that these tests will continue for several months and will include studies of channel improvements for navigation.

The hydraulics of the lock at Cote Ste. Catharine on the St. Lawrence Seaway were studied thoroughly by means of a 1 : 30 scale model, and a 1 : 20 model of a sector gate to be used as an emergency closure on the St. Lawrence Seaway locks had been constructed.

An extension of the theory of
Water Hammer

The substance of a paper read by R. Skalak, Assistant Professor of Civil Engineering, Columbia University, before the Diamond Jubilee Spring Meeting of the American Society of Mechanical Engineers

PART TWO

In the formal solution indicated by eqs. (39) the integrations with respect to ξ would be difficult to carry out in general because the Ω_n values are known as functions of ξ only through the transcendental equation (25). However, some information may be obtained by considering approximations of the integrals for large values of $|z|$ and t.

Consider the part of w given by eq. (31) and, in particular, values of z and t such that :

$$z = c' t \qquad (40)$$

where c' is an arbitrarily selected velocity. Substituting in eq. (31) :

$$w_{2b} = \frac{p_0}{\pi m} \int_0^{\infty} \sum_{\Omega_n} \left[\frac{\sin(\xi c' - \Omega)t}{\left(\frac{\Omega}{c} - \xi\right) D} - \frac{\sin(\xi c' + \Omega)t}{\left(\frac{\Omega}{c} + \xi\right) D} \right] d\xi \qquad \ldots(41)$$

It is found by inspection of D, that the functions $\frac{1}{\left(\frac{\Omega}{c} - \xi\right) D}$ and $\frac{1}{\left(\frac{\Omega}{c} + \xi\right) D}$ are bounded for all of the Ω_n curves for all ξ except for the lowest two curves, Ω_1 and Ω_2, at the point $\xi = 0$. The distinction between the lowest two and the remaining Ω_n curves arises because only the Ω_1 and Ω_2 curves pass through the origin. A physical interpretation of this fact is that only these two lowest modes have finite phase velocities as the wave-length increases indefinitely.

For the higher Ω_n branches, $n > 2$, the integral (41) may be approximated by the method of stationary phase (Ref. 7, p. 505), for the large values of t. This method shows these integrals to be of the order of $\frac{1}{\sqrt{t}}$.

The integrals over the Ω_1 and Ω_2 curves will be broken into two parts; one part from $\xi = 0$ to $\xi = \epsilon$ and a second part from ϵ to ∞, where ϵ is a small positive number. By the stationary phase theorem the portions from ϵ to ∞ are again $0\left(\frac{1}{\sqrt{t}}\right)$. Collecting these results, eq. (41) becomes :

$$w_{2b} = \frac{p_0}{\pi m} \times$$

$$\int_0^{\epsilon} \sum_{\Omega_{1,2}} \left[\frac{\sin(\xi c' - \Omega)t}{\left(\frac{\Omega}{c} - \xi\right) D} - \frac{\sin(\xi c' + \Omega)t}{\left(\frac{\Omega}{c} + \xi\right) D} \right] d\xi + 0\left(\frac{1}{\sqrt{t}}\right) \qquad \ldots(42)$$

Since ϵ may be chosen indefinitely small, the functions in the integrand may be approximated by an appropriate number of terms of their expansions about $\xi = 0$. Consider the first term of the integral with $\Omega = \Omega_1$ which may be written :

$$w_1 = \frac{p_0}{\pi m} \int_0^{\epsilon} \frac{\sin(\xi c' - \Omega_1)t}{\xi\left(\frac{\Omega_1}{\xi c} - 1\right) D} d\xi \qquad \ldots(43)$$

The denominator of the integrand approaches a constant times ξ as ξ approaches zero. The constant is :

$$\lim_{\xi \to 0} \left(\frac{\Omega_1}{\xi c} - 1\right) D = \left(\frac{c_1}{c} - 1\right) D_1 \qquad \ldots(44)$$

where :

$$c_1 = \lim_{\xi \to 0} \left(\frac{\Omega_1}{\xi}\right)$$

$$D_1 = \lim_{\xi \to 0} D(\Omega_1, \xi) = \frac{4\rho_0 c_1^4}{mc^2 a \left(\frac{c_1^2}{c^2} - 1\right)^2} + \frac{2c_0^2}{a^2} \left[\frac{\nu^2}{\left(1 - \frac{c_0^2}{c_1^2}\right)^2} + 1 - \nu^2 + \frac{h^2}{12a^2} \right] \qquad \ldots(45)$$

The constant c_1 is the phase velocity of the slowest waves for wave-lengths approaching infinity. It is very close to the Joukowsky velocity c_e. An expression for c_1 is derived in the appendix.

In the numerator of eq. (43) Ω_1 is replaced by the first two terms of its expansion about $\xi = 0$:

$$\Omega_1 = c_1 \xi - d_1 \xi^3 \qquad \ldots(46)$$

This expansion is developed in the appendix. It is necessary to use two terms of the expansion because the first term alone would result in a vanishing numerator for the case $c' = c_1$.

Using eqs. (44) and (46) in (43) yields :

$$w_1 = \frac{p_0}{\pi m\left(\frac{c_1}{c}-1\right)D_1}\int_0^{\infty}\frac{\sin(\xi z^1+d_1\xi^3 t)}{\xi}d\xi \qquad ...(47)$$

where z' is defined by :

$$z' = (c'-c_1)t \qquad ...(48)$$

The new coordinate z' is the location of any point relative moving at velocity c_1. In eq. (47) the upper limit has been changed from ϵ to ∞. The integral thus added is $0\left(\frac{1}{\sqrt{t}}\right)$ by the stationary phase theorem, and is negligible in the present approximation.

For $z' = 0$, the integral in eq. (47) has a constant value of $\pi/6$ provided d_1 is positive which is the case here. For points where $|z'|$ is large, the term containing ξ^3 may be neglected. Then the integral in eq. (47) becomes $\pm\pi/2$ for $\pm z'$. For points near $z' = 0$ it is convenient to change the variable of integration from ξ to $\eta = \xi z'$. Then :

$$w_1 = \frac{p_0}{\pi m\left(\frac{c_1}{c}-1\right)D_1}\int_0^{\infty}\frac{\sin(\eta+\beta\eta^3)}{\eta}d\eta \qquad ...(49)$$

where :

$$\beta = \frac{d_1 t}{z'^3} \qquad ...(50)$$

From eq. (49) it may be seen that for w_1 constant β must be constant, say β_0.
Then :

$$z' = \sqrt[3]{d_1 t\beta_0} \qquad ...(51)$$

This shows that points for which w_1 is constant continually move away from the point $z' = 0$. To summarise, w_1 is a wave having constant deflection at the point $z' = 0$, i.e. moving with velocity c_1. At points far ahead and far behind this wave front point the deflection is also constant, but the wave front continually spreads out around the point $z' = 0$. Fig. 4 shows the general shape of the wave.

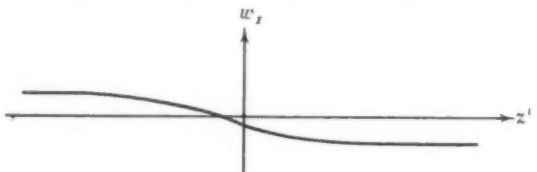


Fig. 4

If the same reasoning that has been used to evaluate w_1 is applied to the remaining terms of eq. (42) similar results are obtained. Thus for large t :

$$w_z = I_1 - H_1 + I_2 - H_2 \qquad ...(52)$$

where :

$$\frac{I_n}{H_n} = \frac{p_0}{\pi m\left(\frac{c_n}{c}\mp 1\right)D_n}\int_0^{\infty}\frac{\sin(z\mp c_n t\pm d_n\xi^2 t)}{\xi}d\xi \quad n = 1, 2 \qquad ...(53)$$

The constants c_2, D_2, d_2 which appear in H_2 and I_2 are defined in the same way as c_1, D_1, d_1 in eqs. (45) and (46) by changing all subscripts from 1 to 2 in these equations. The velocity c_2 is very nearly the velocity of sound in the tube wall, c_0.

The term I_1 is the deflection w_1 discussed above. The H_1 term is a wave of the same velocity and shape as w_1 but of smaller amplitude and travelling in the negative direction.

The H_2 and I_2 terms are also waves of the same shape as w_1, but travelling at the velocity c_2. These precursor waves are found to be very small compared to the main water-hammer waves I_1, H_1 which travel at velocity c_1.

The complete deflection w is the sum of w_{zb}, eq. (52) and w_{za}, eq. (27). The deflection w_{za} is independent of time and its value for large values of $|z|$ may be approximated by the same kind of reasoning as used for w_{zb} for large values of t. The result is :

$$w_{za} = \pm\frac{p_0 a^2}{2Eh\left[1+\frac{h^2}{12a^2(1-\nu^2)}\right]} \quad \text{for } \pm z \qquad ...(54)$$

The term $h^2/12a^2(1-\nu^2)$ will be neglected compared to unity since only thin-walled tubes are considered. Thus :

$$w_{za} = \pm\frac{p_0 a^2}{2Eh} \quad \text{for } \pm z \qquad ...(55)$$

The procedures used to evaluate w may also be used to obtain approximations of p, v and u_z for large $|z|$ and t starting with the general expressions, eqs. (39). The results are :

$$w = \pm\frac{p_0 a^2}{2Eh} + I_1 - H_1 + I_2 - H_2 \quad \text{for } \pm z$$

$$p = \frac{p_0}{2} - \frac{2\rho_0 c_1^2}{a\left[\frac{c_1^2}{c^2}-1\right]}(I_1 - H_1) - \frac{2\rho_0 c_2^2}{a\left[\frac{c_2^2}{c^2}-1\right]}(I_2 - H_2)$$

$$v = \frac{p_0}{2\rho_0 c} - \frac{2c_1}{\left[\frac{c_1^2}{c^2}-1\right]}(I_1 + H_1) - \frac{2c_2}{a\left[\frac{c_2^2}{c^2}-1\right]}(I_2 + H_2)$$

$$u_z = \mp\frac{p_0 \nu a}{2Eh} + \frac{\nu}{a\left[\frac{c_1^2}{c_0^2}-1\right]}(I_1 - H_1) + \frac{\nu}{a\left[\frac{c_1^2}{c_0^2}-1\right]}(I_2 - H_2) \quad \text{for } \pm z \qquad ...(56)$$

These equations lead to four wave fronts in each case as discussed for w. Numerical results for a typical case of water in a thin steel tube are shown in Fig. 5. In the present approximation for large t, the pressure and fluid velocity are again independent of r, i.e. they are constant across any section.

In order to estimate the length over which a given wave front extends, the slope w_z will be computed at the points which move with constant velocity c_1 or c_2. The difference in w before and after a wave front divided by the slope at the wave front point will be indicative of the length of a wave front.

The double integral for w_z is derived from w, eq. (20). The first integral may be evaluated and the result folded by the same procedures used for w. For a point moving so that $z = c_1 t$:

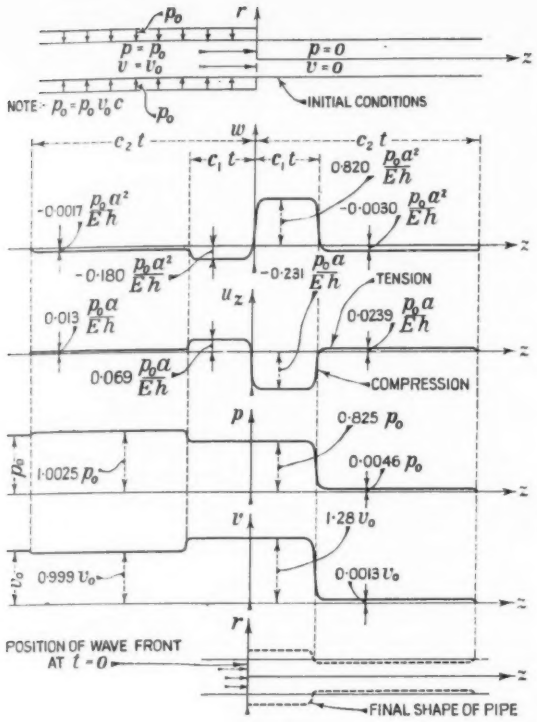


Fig. 5

$$w_z = \frac{p_0}{\pi m}\int_0^\infty \frac{\xi \cos \xi c_1 t}{f(\xi)}\,d\xi + \frac{p_0}{\pi m}\int_0^\infty \sum_{\Omega_n}\left[\frac{\xi\cos(c_1\xi-\Omega)t}{\left(\frac{\Omega}{c}-\xi\right)D} - \frac{\xi\cos(c_1\xi+\Omega)t}{\left(\frac{\Omega}{c}+\xi\right)D}\right]d\xi \quad ...(57)$$

The function $\xi/f(\xi)$ is bounded for all ξ and the first integral in eq. (57) is $0\left(\frac{1}{t}\right)$ by the Riemann-Lebesgue lemmata (Ref. 16, p. 172).

In the second integral the integrand is also bounded. This integral may be approximated by the method of stationary phase. The dominant part of the integral will come from the vicinity of stationary phase points which are defined by :

$$\frac{d}{d\xi}(\xi c_1 \pm \Omega) = 0 \qquad \text{i.e.} \quad \frac{d\Omega}{d\xi} = \mp c_1 \qquad ...(58)$$

In general such points give a contribution which is $0\left(\frac{1}{\sqrt{t}}\right)$, but if :

$$\frac{d^2}{d\xi^2}(\xi c_1 \pm \Omega) = 0 \qquad \text{i.e.} \quad \frac{d^2\Omega}{d\xi^2} = 0 \qquad ...(59)$$

then the contribution of the integral from the vicinity of this point is $0\left(\frac{1}{\sqrt[3]{t}}\right)$ (Ref. 5, p. 40) Eqs. (58) and (59) are both satisfied on the Ω_1 curve at $\xi = 0$. Hence this contribution will predominate over all others for large values of t.

To evaluate the dominant term, the expression for Ω_1, eq. (46), is substituted in eq. (57). Hence for large t:

$$w_z = \frac{p_0}{\pi m}\int_0^\infty \frac{\cos(d_1\xi^3 t)}{\left(\frac{c_1}{c}-1\right)D_1}\,d\xi \qquad ...(60)$$

Changing the variable of integration to $\eta = \xi(\sqrt[3]{d_1 t})$:

$$w_z = \frac{p_0}{\pi m\left(\frac{c_1}{c}-1\right)D_1\sqrt[3]{d_1 t}}\int_0^\infty \cos\eta^3 d\eta \qquad ...(61)$$

This integral (61) is known (Ref. 5, p. 41). Hence :

$$w_z = \frac{p_0\Gamma\left(\frac{1}{3}\right)\sin\frac{\pi}{3}}{3\pi m\left(\frac{c_1}{c}-1\right)D_1\sqrt[3]{d_1 t}} \qquad ...(62)$$

Now the change of w from a location far behind the point $z = c_1 t$ to a location far ahead of the point $z = c_1 t$ is by eq. (49) :

$$\Delta w = \frac{p_0}{m\left(\frac{c_1}{c}-1\right)D_1} \qquad ...(63)$$

Defining the " nominal length " L_1 of the wave

Table I
Nominal Lengths of Wave Fronts for Typical Example

	Time Seconds	Nominal length of wave front. Feet	Distance of wave front from origin. Feet
Primary Wave	1	19·1	3,218
	5	32·6	16,091
Precursor Wave	1	30·0	17,328
	5	51·3	86,640

Assumed Values		Derived Values
Radius of pipe :	$a = 1$ foot	$\frac{a}{h} = 62{\cdot}752$
Velocity of sound in water :	$c = 5{,}000$ ft/sec	$R = 12{\cdot}478$
Density of water :	$\rho_0 = 1{\cdot}94$ slugs/ft³	$\frac{c_1}{c} = 0{\cdot}64365$
Modulus of elasticity of steel :	$E = 30\times10^6$ psi	$\frac{c_2}{c} = 3{\cdot}4656$
Poisson's ratio for steel :	$\nu = 0{\cdot}30$	$\frac{c_0}{c} = 3{\cdot}5324$
Specific weight of steel :	$\gamma_s = 490$ lbs/ft³	$\frac{c_e}{c} = 0{\cdot}64429$
Ratio, $A = \frac{\rho_0 a}{m}$:	$A = 8$	

front to be Δw divided by w_z :

$$L_1 = \frac{3\pi \sqrt[3]{d_1 t}}{\prod\left(\frac{1}{3}\right)\sin\frac{\pi}{3}} \qquad \ldots(64)$$

Computation of the " nominal length ", L_2, of the wave fronts moving at velocity c_2 results in the same formula with d_1 replaced by d_2.

Some numerical values of L_1 and L_2 are given in Table 1. It may be noted that although the length of the wave front is long compared to the diameter of the pipe it is short compared to the distance from the origin that the wave has travelled.

The above computations of the lengths of wave fronts hold also for p, v and u_z because they are described by the same integrals, I_1, H_1, I_2, H_2.

An Extension of Joukowsky's Method

Some of the results derived by use of integral transforms may also be derived by a much simpler procedure which is an extension of Joukowsky's method. The extension consists of taking into account the longitudinal stresses and longitudinal inertia of the pipe wall. This makes possible the precursor type wave which is essentially a tension wave in the pipe wall.

The following derivation follows the general plan of Joukowsky's paper (Ref. 8). The pressure and axial velocity of the fluid are assumed to be uniform over any cross-section of the pipe. The fluid is assumed compressible, its bulk modulus being K. The equation of continuity may then be written in the form :

$$-\frac{\partial v}{\partial z} = \frac{1}{K}\frac{\partial p}{\partial t} + \frac{2}{a}\frac{\partial w}{\partial z} \qquad \ldots(65)$$

The equations of motion of the fluid reduce to :

$$\rho_0 \frac{\partial v}{\partial t} = -\frac{\partial p}{\partial z} \qquad \ldots(66)$$

So far, these are the equations usually used. The new element is the use of the equations of motion of the tube considered as an elastic membrane instead of a ring of no mass. These equations are derived from eqs. (5) and (6) by dropping all terms arising from bending stiffness and rotatory inertia and substituting p for q :

$$\frac{w}{a^2} + \frac{v}{a}u_z = \frac{p}{mc_0^2} \qquad \ldots(67)$$

$$\frac{\ddot{u}}{c_0^2} - u_{zz} - \frac{v}{a}w_z = 0 \qquad \ldots(68)$$

In eq. (67) the term $\dot{w}$ has been omitted because the effect of radial inertia of the tube and of the fluid is neglected as in the Joukowsky theory.

No attempt will be made to solve the equations (65), (66), (67) and (68) in general. It is sufficient for the purpose at hand to show that the system permits solutions which are waves of arbitrary shape moving at either of the velocities c_1 or c_2 without dispersion. A solution is assumed of the form :

$$\left.\begin{aligned} w &= w' f(z+\tilde{c}t) \\ p &= p' f(z+\tilde{c}t) \\ v &= v' f(z+\tilde{c}t) \\ u_z &= u'_z f(z+\tilde{c}t) \\ u_t &= u'_t f(z+\tilde{c}t) \end{aligned}\right\} \qquad \ldots(69)$$

where the primed quantities are constants and $\tilde{c}$ is an unknown constant velocity. The constants u'_t, u'_z and $\tilde{c}$ are related by the requirement :

$$\frac{d}{dt}u_z = \frac{d}{dz}u_t \qquad \ldots(70)$$

Substituting the assumed form (69) into eqs. (65), (66), (67), (68) and (70), there result five linear homogeneous equations involving the five primed constants. In order that these equations have a solution different from zero it is necessary for the determinant of the coefficients to be zero. This condition yields an equation involving $\tilde{c}$ which can be satisfied only if c takes on the values $\pm c_1$ or $\pm c_2$. Thus the velocities at which waves may travel without dispersion in the present consideration are the same as the principal velocities derived in the integral transform method.

A further point of interest is that the ratio of the change in w to the change in p across a wave front is the same in the extended Joukowsky theory and the transform solution. The same is true of any two of the quantities w, p, v, u_z, etc. This is shown by solving for the ratios of interest in each theory with $\tilde{c} = c_1$ or c_2 as the case may be.

These results are of interest because they indicate the significance of the assumptions made in the Joukowsky theory. It shows that c_1 differs from c_e because the Joukowsky theory neglects longitudinal stresses and longitudinal inertia of the pipe. It also shows that the dispersion predicted by the transform method is due to the effects of the bending stiffness and of the radial inertia of the pipe and fluid. The effect of radial inertia is much more important. After the wave disperses somewhat, bending effects are negligible.

Other Initial Conditions

The integral transform method may be applied to certain other initial conditions beside those assumed in the previous discussions. The problem and results shown in Fig. 6 illustrate a second example. The initial conditions are:

$$v = v_0 \text{ for } z < 0$$
$$v = -v_0 \text{ for } z > 0$$
$$p = u = w = u_t = w_t = 0 \text{ for all } z.$$

Under these conditions each half of the pipe simulates the water-hammer problem in which an established flow is suddenly cut off by an instantaneous valve closure. Since by symmetry no fluid crosses the plane $z = 0$, each half of the pipe acts as a closed valve as far as the other half is concerned.

The magnitudes and velocities of the waves may also be established on the basis of the simplified procedure of the previous section. In general, this will be the simpler method. It does not predict dispersion, but it may be assumed that the dispersion characteristics are the same in any case.

Conclusions

The theory developed herein shows the following results which are not contained in the usual theory :

1. If the initial conditions specify a sharp wave front of pressure, this front will gradually disperse over a finite length as it proceeds. This dispersion continues indefinitely so that no steady wave shape is ever reached.
2. Two waves will be generated in general; one which is similar to the Joukowsky result and one which is essentially a tension wave in the pipe

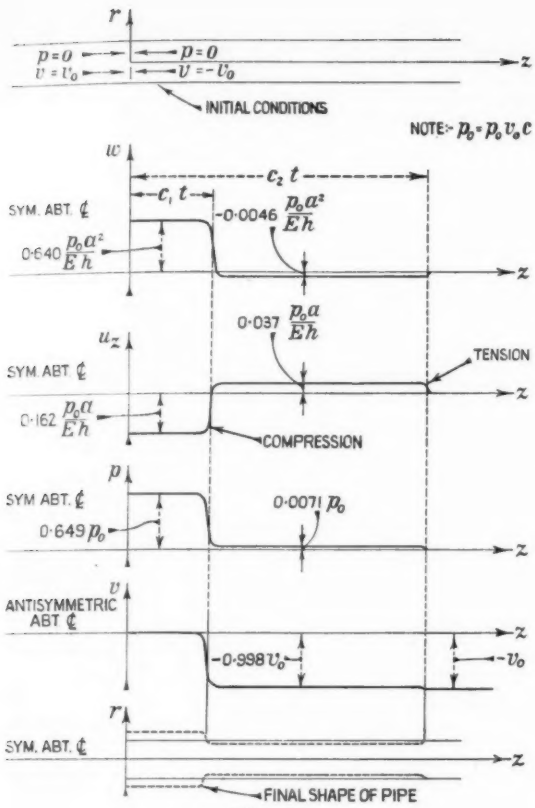


Fig. 6

wall. The pressure change due to this precursor is very small.

3. After a sufficiently long time has elapsed since the generation of a wave there will be one point in each wave front which has a constant deflection and fluid pressure and moves at a constant velocity. This velocity is very close to the Joukowsky velocity for the main pressure wave. For the precursor this velocity is slightly less than the velocity of sound in the pipe wall.
4. The bending stresses in the pipe wall have very little effect on the characteristic velocities and the rates of dispersion after a sufficient time has elapsed. Such stresses can only be significant in the early stages of the motion in regions where the wave front is sharp so that the variation of pressure and deflection is very rapid along the length of the pipe.
5. The relations between fluid velocity, pressure and hoop stress given by the Joukowsky theory are substantially correct, but there are also longitudinal stresses in the pipe not predicted by the usual theory.
6. Available experimental data (Ref. 2) are in very close agreement with the predictions of the Joukowsky theory as to the pressure rise and velocity of the main pressure wave. Inasmuch as the analysis presented in this paper gives essentially the same results as the Joukowsky theory for these items, it is confirmed experimentally. However, there are no experimental data available on the precursor wave or the rate of dispersion predicted herein.

Acknowledgments

The author is grateful to Professor H. H. Bleich for his advice and encouragement throughout the preparation of this paper and the thesis on which it is based. This research was partially supported by the Office of Naval Research under Contract Nonr 266(08).

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Appendix

Expansion of Ω_1 and Ω_2 About $\xi = 0$

The values Ω_1, Ω_2 are defined as the lowest two roots of eq. (25). From the numerical results represented by Fig. 2, it is expected that both Ω_1 and Ω_2 approach zero as ξ approaches zero. Hence, Ω_1 and Ω_2 have an expansion of the form :

$$\Omega = \bar{c}\xi - d\xi^3 + \ldots . \qquad (71)$$

where only odd powers occur because the Ω_n are odd functions of ξ. The values of $\bar{c}$ and d are determined by substituting this expansion in eq. (25) and equating the coefficient of each power of ξ appearing to zero.

The terms $1/N$ and Δ in the transcendental equation (25) are given fully by eqs. (23) and (24). Expanding the Bessel functions, Δ may be written in the form :

$$\Delta = \frac{\left[1 - \frac{a^2}{4}\left(\frac{\Omega^2}{c^2} - \xi^2\right) + \frac{a^4}{64}\left(\frac{\Omega^2}{c^2} - \xi^2\right)^2 + \ldots .\right]}{\frac{a^2}{4}\left(\frac{\Omega^2}{c^2} - \xi^2\right)\left[1 - \frac{a^2}{8}\left(\frac{\Omega^2}{c^2} - \xi^2\right) + \frac{a^4}{192}\left(\frac{\Omega^2}{c^2} - \xi^2\right)^2 + \ldots .\right]} \qquad \ldots(72)$$

In order to be able to clear eq. (25) of fractions, the quotient of the two infinite series in eq. (72) is written

as a single series :

$$\Delta = \frac{1}{\frac{a^2}{4}\left(\frac{\Omega^2}{c^2}-\xi^2\right)}\left[1-\frac{a^2}{8}\left(\frac{\Omega^2}{c^2}-\xi^2\right)-\frac{a^4}{192}\left(\frac{\Omega^2}{c^2}-\xi^2\right)^2+\ldots.\right] \qquad \ldots(73)$$

Using this value the transcendental eq. (25) may be put in the form :

$$\frac{2\rho_0\Omega_2}{ma}\left(\frac{\Omega^2}{c_0^2}-\xi^2\right)\left[1-\frac{a^2}{8}\left(\frac{\Omega^2}{c^2}-\xi^2\right)-\frac{a^4}{192}\left(\frac{\Omega^2}{c^2}-\xi^2\right)^2+\ldots.\right]+$$
$$+\Omega^2\left(\frac{\Omega^2}{c^2}-\xi^2\right)\left(\frac{\Omega^2}{c_0^2}-\xi^2\right)\left[-1-\frac{h^2\xi^2}{12}\right]+$$
$$+\left(\frac{\Omega^2}{c^2}-\xi^2\right)\left(\frac{\Omega^2}{c_0^2}-\xi^2\right)\frac{h^2c_0^2}{12}\left[\frac{1}{a^4}+\xi^4\right]+$$
$$+\left(\frac{\Omega^2}{c^2}-\xi^2\right)\frac{1}{a^2}\left[\Omega^2-c_0^2(1-\nu^2)\xi^2+\right.$$
$$\left.+\frac{\nu h^2c_0^2\xi^4}{6}+\frac{c_0^2h^4\xi^6}{144}\right]=0 \qquad \ldots(74)$$

Now the assumed expansion given by eq. (71) is substituted above for Ω. The result is a series of the form :

$$b_1\xi^4+b_2\xi^6+b_3\xi^8+\ldots.=0 \qquad (75)$$

Each coefficient b_n of this series must be zero since the value Ω is a root of the transcendental eq. (25). Equating b_1 to zero and neglecting h^2/a^2 compared to unity yields an equation involving $\bar{c}$ but not d. This is interpreted as an equation on the yet unknown $\bar{c}$. The roots are :

$$c_1, c_2 = c\left[\left\{2AR+R+R^2(1-\nu^2)\mp\right.\right.$$
$$\left.\left.\mp\sqrt{[2AR+R+R^2(1-\nu^2)]^2-4R^2(1-\nu^2)(2A+R)}\right\}\div\right.$$
$$\left.\div 2(2A+R)\right] \qquad \ldots(76)$$

where :

$$R=\frac{c_0^2}{c^2} \qquad A=\frac{\rho_0 a}{m} \qquad \ldots(77)$$

Equating b_2 to zero yields an equation involving both $\bar{c}$ and d. The equation is considered to determine two values of d, one for $\bar{c}=c_1$ and one for $\bar{c}=c_2$. The solution of the equation $b_2=0$ for d yields :

$$d = ca^2\times$$
$$\times\left\{(A+4)\left[\left(\frac{\bar{c}}{c}\right)^5-\left(\frac{\bar{c}}{c}\right)^3(1+R)+\left(\frac{\bar{c}}{c}\right)R\right]\right.$$
$$\left.-\left(\frac{\bar{c}}{c}\right)\frac{h^2}{12a^2}(1+2R^2\nu)\right\}\div$$
$$\div\left\{-16\left(\frac{\bar{c}}{c}\right)^2(2A+R)+8R(2A+1)+8R^2(1-\nu^2)\right\} \qquad \ldots(78)$$

Tenders for New Zealand Schemes

The State Hydro-Electric Department of New Zealand has called for tenders for the supply of electrical equipment to be used in various hydro-electric projects.

Brief specifications are as follows:

One 30,000 kVA 66/11 kV tcol transformer bank and spare unit for the Bromley substation in the Christchurch district, to be delivered at Lyttelton. Tenders should reach the Secretary, Tenders Committee, State Hydro-Electric Department, not later than 4 p.m. on February 27, 1956.

Eleven kV indoor switchgear for the Bromley substation, to be delivered at Lyttelton. Tenders should reach the Secretary of the Tenders Committee by March 20, 1956.

Twelve three-phase 66 kV 1,500 MVA circuit breakers for the Hororata substation, to be delivered at Lyttelton. The closing date for this contract is February 28, 1956.

One 100,000 kVA 220/110/11 kV transformer bank and spare unit for the Otaharu substation, to be delivered at Auckland. The closing date for tenders is February 7, 1956.

One 15,000 kVA 11/11/50 kV tcol transformer bank and spare unit together with one three-phase 11 kV earthing transformer for the Atiamuri power station. to be delivered at Auckland. Tenders close on January 24, 1956.

One 2,500 kVA 11 kV regulating transformer and earthing transformer for the Kikiwa substation, to be delivered at Wellington. The closing date for tenders is February 14, 1956.

One 50 ton electric overhead travelling crane for the Kikiwa substation to be delivered at Wellington. Tenders should be submitted by February 28, 1956.

One 10,000 kVA 11/33 kV transformer bank and spare unit for the Mangahao power station, to be delivered at Wellington. Tenders close on March 6. 1956.

One hundred and fifty MVA 11 kV switchgear for the Kikiwa substation to be delivered at Wellington. Tenders should be submitted by January 31, 1956.

Rubber Waterstops. A leaflet from Hall & Hall Limited, Hampton, Middlesex, gives details of a range of rubber waterstops they manufacture for all kinds of hydraulic structures. Four standard sections are available in single lengths up to 60 ft. and vulcanised splices can be formed to produce longer lengths up to any reasonable figure. Moulded intersections of both flat and tee types are also available. The sections are such that they key firmly into the concrete without introducing any problem in concrete placing. The waterstops have an average tensile strength of 2,100 lb. per sq. in. and an elongation at break of about 350 per cent.

Mobile Cranes. A leaflet from Ransomes & Rapier Limited presents the specification and leading features of the Rapier 10 Super mobile crane. It will handle loads up to 10 tons and has a full-circle slewing superstructure mounted on a self-steering rubber-tyred chassis. It is powered by a diesel or petrol engine and has electrical transmission to all movements. A second leaflet describes the use of the Rapier 8 and 10 Super mobile cranes for handling cargo. All mobile cranes carry a three-years' guarantee against mechanical breakdown.

Book Reviews

Davis Dam and Power Plant. United States Bureau of Reclamation, Denver, Colorado. 415 pp. 276 ff. Price $3·25. This volume is the latest of the U.S. Bureau of Reclamation's series of "technical records of design and construction"—a most valuable series which describes in meticulous detail the design features and methods of construction of some of the Bureau's most important works.

Davis Dam is located on the Colorado River 34 miles west of Kingham, Arizona, and impounds a total of 1,820,000 acre ft. at an elevation of 647 ft. It is an earth and rockfill structure 1,600 ft. long at crest level. The power plant, which is served by a forebay channel via an intake structure and penstocks, is of the semi-outdoor type and consists of five MVA sets.

The description is divided into four parts. Part I contains discussions of general planning and historical data, and includes sections summarising costs and initial operation and maintenance. Geological investigations and foundation grouting and treatment are discussed in Part II. Part III, containing seven chapters, is devoted to discussions of the design of the various structures, the design of each main structure with its ancillary equipment being made the subject of a separate chapter. Part IV, devoted to construction, contains no less than 12 chapters. Unlike Part III, the sequence of exposition is not that of the structures involved but of the progressive phases of construction. Thus, for example, concrete placement is treated in a single chapter which covers all the structures concerned. Seven appendices conclude a most painstaking piece of work.

Control of the Economic Loading of a Large Hydro and Thermal Power System. By Sven Stage. Svenska Vattenkraftföreningens Publikationer 454 (1955:11). Föreningens Expedition, Norrlandsgatan 16, Stockholm C. Price: 4 Swedish kroner.

Load control on an electrical network based on a mixture of hydro and thermal power can be a complex business if the best use is to be made of the resources available. The theoretical basis of this control has been thoroughly analysed in this publication, the author of which is the chief electrical engineer of the Sydsvenska Kraft AB, Malmö, and Mr. Stage's analysis forms the basis of the control exercised over his own system.

In his analysis the author distinguishes between plant in a condition of unrestricted operation, meaning that the amount of power produced, delivered or received can be both increased and decreased, and plant operating at limit value, where the foregoing condition of freedom does not hold. When practically the whole of the power sources are operating at limit values these values determine the whole operation and calculations are unnecessary, but the more the conditions of operation approach the unrestricted phase, the greater is the need for mathematical analysis if the utmost overall economy is to be achieved.

The author then introduces the conception of the "incremental cost per kWh," and propounds his fundamental thesis that "if the operation of the power system is correct the incremental cost per kWh at any time measured at one and the same point on the network will be the same for all power sources with unrestricted operation." This thesis is then developed mathematically and applied to various arrangements of hydro and thermal stations.

This treatise was written in Swedish in 1947 and has just been published in English for the benefit of engineers in other countries.

Waterhammer Analysis. By John Parmakian. Published by Prentice Hall, Inc., New York. 161 pp. Price $6·50 or £2 12s. 0d.

The need for a satisfactory introduction in English to the more abstract French and German texts on waterhammer is evidenced by five prominent American turbine manufacturers sponsoring John Parmakian's "Waterhammer Analysis" for Prentice Hall's "Civil Engineering and Engineering Mechanics" series. The author is attached to the U.S. Bureau of Reclamation and a well-known contributor on waterhammer problems to the ASME Proceedings.

The book has its foundations in a course of lectures at the University of Colorado and brings together in 18 chapters a wealth of experience condensed in convenient and readily understandable form with a little formal but elementary mathematics. After touching on rigid-water-column theory and its limitations the author proceeds to the elastic-water-column theory for variable flow in anchored pipes, with and without expansion joints, and outlines the physical significance of the fundamental equations derived from dynamic equilibrium and continuity relations. This is subsequently coupled with two chapters determining the waterhammer wave-propagation velocity and reflection factors for various forms of construction met in practice.

Consideration of waterhammer accompanying rapid and slow gate movements leads up through conjugate waterhammer equations to graphical analysis, better known on this side of the Atlantic as the Schnyder Bergeron method, which is freely used for ascertaining waterhammer at any point in the conduit for any gate location and opening or closing law, including interesting special cases such as turbine guide-vane closure with relief vane and rhythmic motion due to governor action.

The three chapters on waterhammer in pump discharge lines during starting, stopping, and following electric power-supply failure, coupling phenomena associated with valve closing, conduit, pump and motor characteristics at different stages is a valuable summary of methods which were hitherto only accessible in published articles by Parmakian and others. A later chapter covers the design and operation of air chambers which, while useful to water-supply engineers, is of limited application for hydro-electric schemes.

At this stage the influence of friction, previously disregarded, is considered, assuming losses concentrated at the turbine intake, pump outlet or distributed along the pipe, and the effects of branched pipes, in the form of surge chambers, dead ends and breeches pieces with control valves on each, are reviewed as practical aspects of the simpler initial treatment.

It would be misleading to suggest that this book provides answers for all waterhammer problems, but with a concise lucid style, clear printing, adequate bibliography and graphs for approximate solutions at

the project stage, it fills a vacant place in waterhammer literature. If any criticisms are justified, they might be directed at the scanty data on valve and turbine regulating guide-apparatus discharge characteristics and the cursory treatment of surge chambers for pumping and generating stations for the more complex conditions commonly encountered nowadays, with underground stations, although these can admittedly be solved by the methods outlined or by reference to more advanced publications.

Rural Electrification Reports. Sales section, European Office of the United Nations, Palais des Nations, Geneva, Switzerland. $0·20 (U.S.), 1s. 6d. stg. or 0·75 Swiss franc for each document, or may be ordered through Sales Agents for United Nations Publications in local currencies.

The United Nations Economic Commission for Europe (ECE) has made available a number of studies on problems of rural electrification. The papers were prepared by Rapporteurs as part of the effort of the ECE Committee on Electric Power to enable various European countries to compare and learn from each other's experiences in solving the problems. The papers made available to date are entitled:

Utilisation of ultra-violet rays in agriculture
Operation of wind-driven power plants in parallel with low-capacity hydro and thermal plants
Regulation of the tension in rural low-tension distribution networks
Examination of the rate of expansion of rural networks and agricultural plants (length, voltage)
Standardisation of tensions used in agricultural plants
Use of electric light for the hot-house forcing of vegetables and early produce, and supplementary lighting of hen-houses to increase egg production
Formulation of a method for heating hot-houses by electricity and waste steam from thermal plants for the purpose of growing vegetables and early produce throughout the year
Formulation of a system for electrified spraying plant on the artificial rain principle
Protection of the rural population against any excess voltage occurring in overhead low-tension transmission lines during storms

Further studies in this series will appear from time to time in the future.

Medicine Creek Dam: Technical Record of Design and Construction. United States Bureau of Reclamation, Denver, Colorado. 99 pp. 52 ff. Lithographed, in stout paper covers. No price quoted.

Medicine Creek dam forms part of the Missouri River Basin Project, and regulates the waters of Medicine Creek, in south-western Nebraska, for flood control and irrigation. It is a zoned rolled earthfill construction containing 2,700,000 cu. yds. of material, and is 115 ft. above streambed, 165 ft. above the lowest point of excavation, and has a crest length of 5,665 ft. In the left abutment is an uncontrolled concrete spillway, with stilling basin, of 97,800 cusecs capacity, and adjacent to the right abutment are the outlet works leading to a horseshoe conduit of 8 ft. equivalent diameter.

This publication gives a detailed technical account of every phase of the design and construction of the dam. The book is divided into six chapters. The first briefly describes the dam and ancillary works and outlines its history, purpose, and authorisation. The second covers regional and site investigations, and the third deals exhaustively with the design of the dam, spillway, and outlet works. Contract administration is covered in the fourth chapter. In the fifth chapter equally exhaustive treatment is accorded to construction, including cut-off trench and diversion, embankment placement, spillway, outlet works, and concrete production and control. Chapter six describes test installations, and the publication concludes with a number of appendices. In short, the life story of a large earthfill dam is surveyed with admirable thoroughness.

Berechnungsgrundlagen für Bauten (Design Data for Structures). Compiled by Bernhard Wedler. Published by Wilhelm Ernst & Sohn, Berlin-Wilmersdorf, 6·8 in. by 8 in., 463 pp., 277 ff. Distributed in the United Kingdom by Lange, Maxwell & Springer Ltd., London, N.W.1. Price, cloth bound, 18s. 5d.

This is the 22nd Edition, revised and enlarged, of a German standard compilation which extends in scope from foundation work to portable structures of all kinds, merry-go-rounds included. There is no special section for hydraulic structures, but, not to mention the initial general chapter on loads, building materials, etc., the section on foundation and masonry work, as well as on steel structures, will be of interest to the civil engineer dealing with hydro-electric developments. The subsection on pit-head gears and derricks contains an abundance of data, which, pending the contemplated publication of a special subsection now under revision, will be useful to the designer of transmission towers. The layout of the book is excellent, and decimal classification is used. In addition to the usual table of contents, a second table gives the contents in the order of the DIN-numbers (German Standards) involved, and the latter are also stated in the index.

From page 7

Results Obtained

In all, 873 spot elevations were obtained by means of helicopter soundings. The early stages of this operation were primarily experimental and the production in quantity of soundings was low. However, at the close of our operation, using the heavier equipment, 394 soundings were obtained in a total flying time of 20 hours, averaging approximately 20 soundings per hour.

Accuracy, where it was possible to make a check, was sufficient to justify the continued use of this method. Unfortunately, no checks have as yet been possible in the unnavigable areas sounded. Doubtless accuracies will prove to have been influenced by such factors as the type of equipment used and on the speed, depth, and river-bed characteristics of any particular area.

The general conclusion we have drawn is that the heavier the equipment—within reason—the more accurate the results obtained. Further, in the event of more soundings of this type being required we should attempt to simplify the equipment to approach the point where sounding from a helicopter would be the same as manual sounding from a boat—which may be quite possible, using the powerful Sikorski S-51 machine.

Effect of Modern Constructional Methods on Tunnel Design

In this concluding section, Prof. Dr. techn. L. v. Rabcewicz, Sentab, Stockholm, discusses the calculation of the forces acting on a lining and considers lining design

PART TWO

THE static conditions of a lined and grouted tunnel are very complicated. Three different zones surround the free space: the concrete lining, the grouted zone of jointed and loosened rock, and the zone of untouched rock. These zones are bound together by grouting in such a way that the lining cannot act as an independent static member, but on the other hand the forces which became active during the excavation will doubtless be largely taken up by the surrounding rock. In certain cases such as in an irregularly shattered but otherwise sound rock the grouted zone can become so consolidated that the lining could be demolished without causing the rock to loosen. On the contrary, in a stratified rock with a strike running parallel to the axis as shown in Fig. 6, grouting will be unable to prevent loosening of some portions of rock if the lining be removed. In shales and similar materials which are inclined to deteriorate by seepage, grouting, though greatly improving the technical properties of the rock, will not consolidate the surrounding zone sufficiently to make it self-supporting without a lining.

In order to find a solution which covers all these various cases and avoids complicated and problematic calculations, the author has made the simplifying assumption that the lining, acting independently as a three-pinned arch which cannot yield, is loaded by the whole of the rock loosened by excavation. The influence of grouting in improving the ability of the surrounding zone to take load, as well as the load-carrying effect of temporary support, is left out of consideration.

The increase of stress at the borders by slight deviations of the thrust line from the axis, neglected in these simplifications, is largely counteracted by the diminution of load by the bearing action of the consolidated ground arch.

In Figs. 7, 8 and 9 a series of examples is given showing graphic calculations of forces operating on an arch by loads arising from excavation and lining according to the different methods explained above.

In Fig. 7 a circular tunnel of 9 m. diameter is assumed to be loaded by parallel vertical forces, and the polygons of forces are drawn therefrom. The depth of advance has been taken at $t = 3$ m. The polygon for steel arches with $H_1 = B/2$ does not take into account any reinforcing action of the ribs, and the effect of the natural arching has likewise been omitted when drawing the polygon for roofbolting with $H_1 = l$.

A low grouting pressure of 3 kg. per cm. (the forces working radially) has been taken to draw the polygon therefrom in Fig. 8.

The same examinations have been carried out for forces applying to the roof obliquely in Fig. 9. This condition arises very often if for instance an inclined fault zone with parallel slickensides runs parallel with the axis of the tunnel.

In order to compare the effect of the form, an arch with a low ratio between height and width has been chosen, stressed by the same vertical symmetrical loading as the semicircle and the polygon drawn therefrom (Fig. 8).

The drawing of the polygons is started at the point where a large radius coincides with a maximum of load. There the passive force must be zero.

To calculate the arch thickness d a pressure stress of 50 kg. per sq. cm. has been chosen, corresponding to a concrete compressive strength of 250 kg. per sq. cm. The thickness d is understood to be the limit of the so-called "A line," inside of which neither portions of rock nor detrimental parts of temporary support are permitted. In view of the liability to inclined load the maximum thickness obtained by the calculations should be taken over the whole arch.

When calculating d for grouting pressure a pressure stress of 125 kg. per sq. cm. has been allowed, as the forces with grouting can be kept under control and stress the lining only once. To avoid an un-

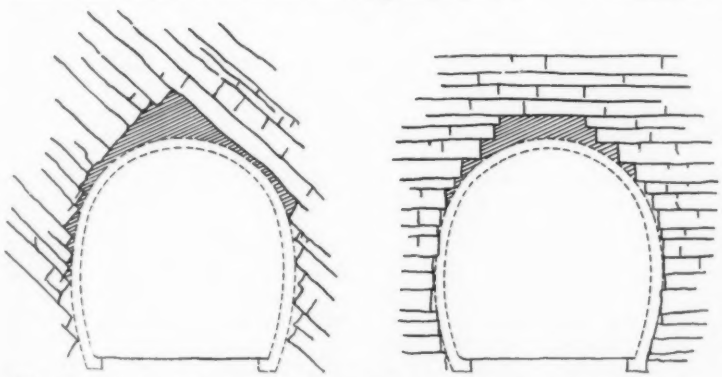


Fig. 6. Sketch of loosening in grouted rock on removal of the lining. (left) strata dipping, (right) strata horizontal

FIG. 7

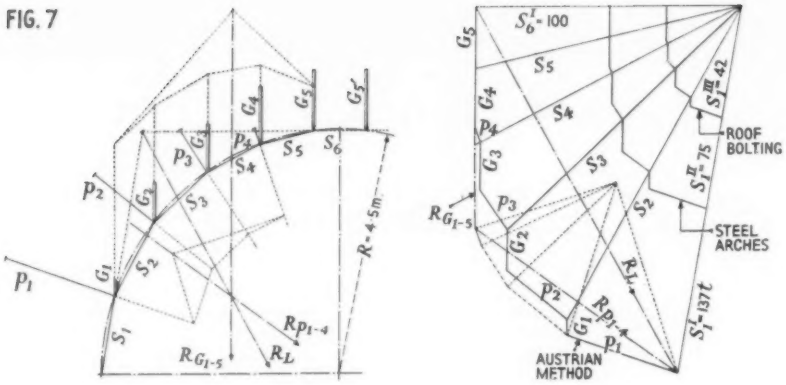


Fig. 7. Circular arch loaded by parallel vertical forces

FIG. 8

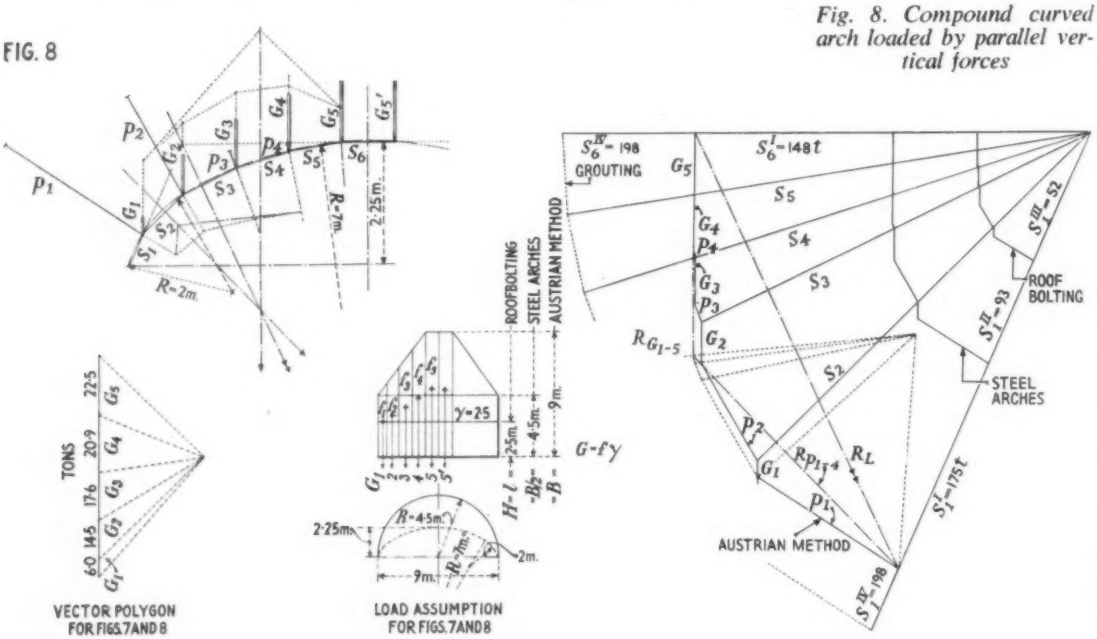


Fig. 8. Compound curved arch loaded by parallel vertical forces

necessary increase in lining thickness in vertical or slightly curved sidewalls to withstand grouting pressures, these portions have to be bolted and reinforced accordingly.

In special cases d will have to be increased on account of practical considerations, such as manageable minimum thickness of concrete or minimum concrete cover inside the intrados of steel arches.

In Table I a summary is given of the analysis, stating the decisive forces and the dimensions of the lining derived therefrom together with the practical minimum thickness.

The static condition of the arch for the Austrian method in Figs. 7, 8 and 9 must theoretically lead to a deformation if the tunnel is not grouted before taking off the formwork, as the weight of loosened rock is not sufficient to exert the necessary passive resistance. But from a practical standpoint there will be very little danger of deformation, at least for quite a time, as a well-compacted concrete will fill the space solidly, exerting a pressure of 2 to 3 kg. per sq. cm. against the rock face. By pumping the concrete even the arch closure can be expected to be filled satisfactorily. But even should it not have been possible to compact the uppermost part completely, nothing will happen, at least not for a considerable time to come, for when the load is transferred from temporary support to the concrete, some unloading takes place and it takes a certain time until the load has regained its former magnitude. Anyhow, as it is quite clear that grouting should not be omitted, being the only means of consolidating the surroundings properly, it is certainly better to grout the tunnel as soon as possible, preferably before taking off the form.

After what has been said, it can more easily be understood why tunnels made according to the old methods so frequently gave rise to difficulties during construction and expensive repair work afterwards. Today many more tunnels are driven and lined per year throughout the world using larger sections than during the zenith of railway tunnelling, but relatively little is reported about failures or difficulties caused by rock pressure. This may well be due partly to better methods of geologic investigation, but primarily it is the result of the more favourable properties of modern tunnelling regarding development of load.

FIG. 9

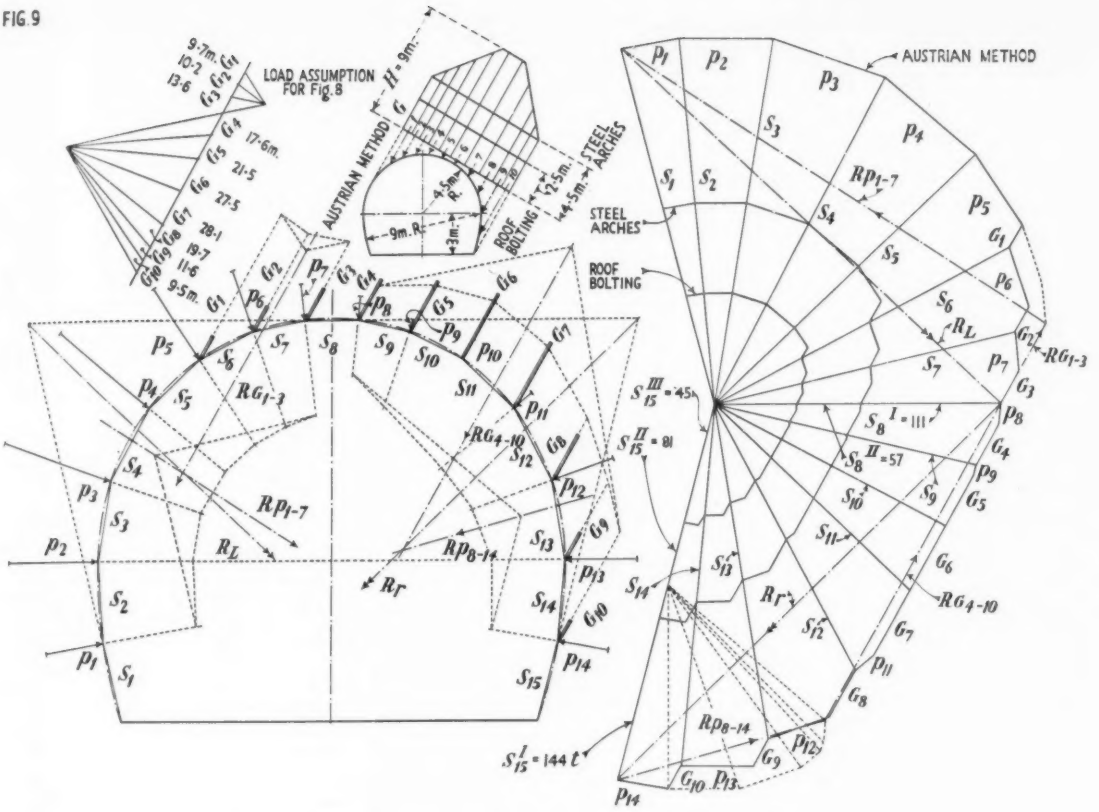


Fig. 9. Circular arch loaded by oblique parallel forces

We must mention here an obsolete method of static calculation of a lining which was rather widely used in the past, as it has still not entirely fallen into disuse.[6] The method is based on the classic theory of earth pressure. According to this method a load is assumed which strains the roof into an elliptic form the height of which is derived from the amount of settling and of permanent loosening of the material. A funicular polygon is drawn and the lining designed in such a way that the thrust line remains inside the middle third. An unnecessarily heavy arch of parabolic form is obtained in this way, the axis of the arch coinciding with that of the ellipse of loads. If a lining designed in this way for vertical forces happens to be subjected to oblique forces the thrust line is displaced far beyond the middle third. To answer the basic demands of the method in this case the axis of the arch must be turned over or the thickness of the lining has to be increased considerably.

To make a comparison possible a lining has been designed for the same example on these principles and the dimensions sketched in Table II together with those for the other methods. Excavation and lining have been assumed to be made according to the Austrian method.

Strange to say, it is perhaps partly owing to the peculiarities of this obsolete method of design that many tunnels which were built in accordance with it still serve their purposes in spite of so many imperfections of old-time tunnelling, as the lining generally was made much too strong. Local conditions may have helped to some extent to increase passive resistances to an adequate amount, and last but not least, where the lining really deformed, it may have been either tolerated or in many cases not even observed.

It may be of interest to make an economic comparison between the methods in order to be able to evaluate the influence of the different methods upon costs. Table II gives a calculation of direct costs for Swedish conditions for 1 m. run of lining a tunnel of the finished area assumed above according to the requirements of the various methods discussed. An amount of 15 cm. overbreak outside the "A" line has been taken into consideration, and in order to be able to estimate the influence of wages the required number of working hours has been stated.

The proportion of costs for steel arching and the Austrian method compared with roofbolting amounts according to 1 : 1·5 : 2·4, whereas the lining designed in the obsolete method described receives the comparative figure of 3·4, and if grouted even 4. The costs stated in Table II are so-called "direct" costs. They do not include expenses for machinery, construction facilities, administration, risk and profit.

It is perhaps worth mentioning that a somewhat modernised "Belgian" method in the States called the "flying-arch method" is economically and technically more favourable than the once so-famous Austrian system. For European and similar conditions the high cost of material for steel arches makes it necessary to

TABLE I. REQUIRED THICKNESS d OF CONCRETE LINING FOR A TUNNEL OF 9 M. SPAN, EXECUTED ACCORDING TO DIFFERENT TUNNELLING METHODS

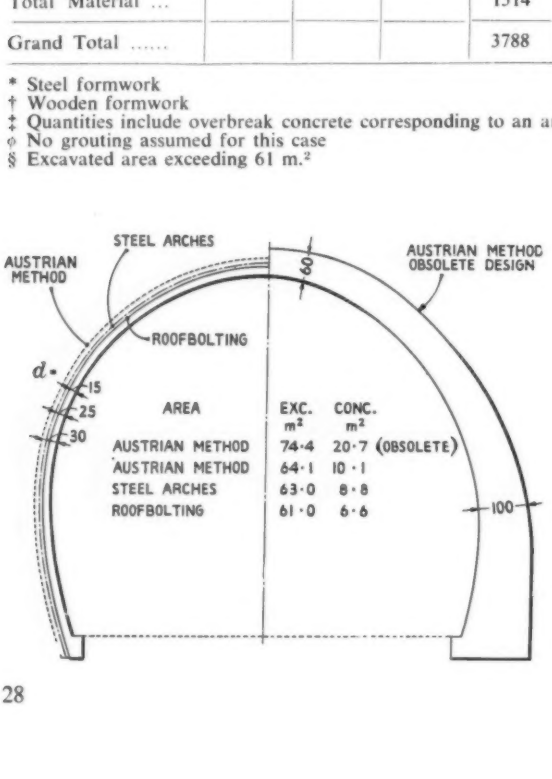
Form of lining	Nature of active forces	Tunnelling Method: Austrian S	Austrian d theor.	Austrian d pract.*	Steel arches S	Steel arches d theor.	Steel arches d pract.*	Roofbolting S	Roofbolting d theor.	Roofbolting d pract.*
		tons	cm.		tons	cm.		tons	cm.	
Circular arch	Rock load vertical	137	27	27	75	15	25	42	8	15
	Grouting	134	11		134	11		134	11	
Circular arch	Rock load inclined	144	29	29	81	16	25	45	9	15
	Grouting	134	11		134	11		134	11	
Compound curve..	Rock load vertical	175	35	35	93	19	25	52	10	16
	Grouting	188	16		198	16		198	16	

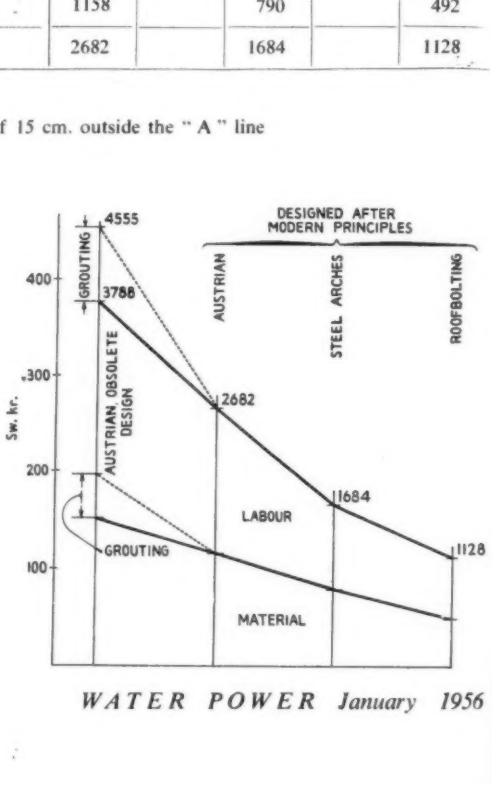
* Thickness of lining d decided from practical considerations
S = maximum tangential force according to polygons Figs. 7-9.
Admissible stresses: with rockload, pressure 50 kg. per sq. cm.; with grouting, pressure 125 kg. per sq. cm.

TABLE II. COMPARISON OF DIRECT COSTS OF LINING PER 1 M. OF TUNNEL

	Method			Austrian Obsolete design		Austrian Design based on modern tunnelling principles		Steel arches		Roofbolting	
	Item	Unit	@ Sw.cr.	Quant.	Cost Sw.cr.	Quant.	Cost Sw.cr.	Quant.	Cost Sw.cr.	Quant.	Cost Sw.cr.
Labour	Working hours	h	6	379	2274	254	1524	149	894	106	636
Material	Formwork	m^2	2·6*	20	104	20	104	20	52	20	52
	Concrete	m^3	5·2† 50 ‡	20·7	1035	10·1	505	8·8	440	6·6	330
	Grouting	m^3	110	φ	—	4·2	462	2·2	242	1·0	110
	Excess Excavation§	m^3	28	13·4	375	3·1	87	2	56	—	—
Total Labour					2274		1524		894		636
Total Material ...					1514		1158		790		492
Grand Total					3788		2682		1684		1128

* Steel formwork
† Wooden formwork
‡ Quantities include overbreak concrete corresponding to an area of 15 cm. outside the " A " line
φ No grouting assumed for this case
§ Excavated area exceeding 61 m.²





choose methods which as much as possible avoid leaving the arches in the concrete.

Though the factor of safety is a function of the degree of knowledge about forces and material we have to deal with, it is certainly against the principles of sound engineering to choose too high a factor in our case, all the more so as the uncertainties can well be kept within certain limits. When designing a lining according to the principles shown above the factor of safety becomes between 4 and 5 only by choosing the admissible stress of concrete adequately. This figure is very much increased by the ground arch taking a part of the load, eventually aided by the reinforcing action of steel ribs. The final safety factor, being consequently much higher than 5, must be considered as satisfactory in every respect as it still safely covers even exceptional cases of maximum load.

This means that larger or smaller roof loads than the assumed averages will decide merely the choice of temporary support. But the thickness of the concrete lining can be left the same throughout a tunnel of a certain section for the same method of excavation provided the geological conditions are within the contemplated range.

For squeezing or swelling rock or for tunnelling through earth stronger linings are necessary. But as these cases are relatively rare and easy to recognise, this simple and economic method of designing a lining according to the properties of modern methods can be used, in the author's opinion, for almost all tunnelling through unstable rock.

REFERENCE

[1] Kommerell, O., "Statische Berechnung von Tunnelmauerwerk," W. Ernst & Sohn, Berlin, 1912, 1941.

"Atlas Diesel" Changes its Name

The worldwide group of companies headed by A.B. Atlas Diesel, Stockholm, will be known as "Atlas Copco" from January 1, 1956. This decision is the almost inevitable result of a phenomenal expansion from a progressive Swedish manufacturing firm to a world organisation, and of the decision taken in 1948 to concentrate exclusively on compressed-air equipment.

The company originated in 1873, when a factory was built in Stockholm to produce railway rolling stock, ship's boilers, bridges and other ironwork. Manufactures of this kind naturally entailed the widespread use of pneumatic tools, and this led the company to design and make its own compressed-air equipment, first for its own use and then for sale. In 1898 the Atlas Company acquired the Swedish patents taken out by Rudolph Diesel and commenced the manufacture of diesel engines.

In 1948 the company had to make a vital decision, for both its diesel and its compressed-air business had grown beyond capacity. The diesel interests were therefore sold to A.B. Nydqvist & Holm, one of Sweden's leading builders of water turbines, and all the company's resources were concentrated on compressed-air equipment. Over the past ten years the group has expanded to such an extent that it is now believed to be the largest organisation in the world devoted exclusively to the manufacture of compressed-air equipment. In 1946 the group consisted of three companies overseas—the oldest being that in Great Britain—whereas now there are 26. The turnover has increased sevenfold since 1945, and export sales have increased from one-third to three-quarters of the total production during the ten-year period. Mention should also be made of the company's pioneer work in introducing what is universally known as the "Swedish" method of tunnelling.

In the course of this rapid development the word "Diesel" has become an anachronism, and further, the names of some of the overseas companies did not reveal their parentage clearly. It has therefore been decided to dispense with the word "Diesel" and to alter the names of all companies, including the parent company, to include the term "Atlas Copco" where this is not already in the title. The word "Copco" is an abbreviation of the original title of the Belgian company—"Compagnie Pneumatique Commerciale."

New Zealand Prospects

According to the Annual Report of the New Zealand Ministry of Works, reconnaissances with a view to possible power development in the future were made during the previous year of the central volcanic region between Turangi and Waiouru and of the Bay of Plenty rivers extending eastward from the Rangitaiki to the Motu. Reconnaissances were also made of the Ngaruroro River in Hawke's Bay. So far as it was possible to judge on the information at present available the total potential of the Bay of Plenty rivers was considerable.

Referring to the possibility of Tongariro development, the report says that though the nature of the terrain called for specially careful consideration, the diversion into Lake Taupo and the Waikato River of a considerable flow from the Wanganui and other rivers flowing off the mountain peaks appeared to be practical. Such a diversion should not only make possible a development of the order of 200 MW in the upper Waikato, but the additional water would generate extra units in all the lower Waikato stations, the equivalent of a large generating station. It was proposed to put in hand field investigations of this important potential.

A reconnaissance of the Egmont area would be made in the near future. This would include all the main streams flowing west and south between Kawhia and Wanganui. Eight power projects—Huka, Aratiatia, Parariki, Okataina, Tarawera and three projects on the Kaituna River—were at present under investigation. In addition seven major projects—alternative schemes for development of the Te Anau-Manapouri lake system in the South Island—were in the initial planning stage. The main field effort had been in the Rotorua area.

Spheroidal-Graphite Iron Castings. A technical leaflet issued by Armstrong Whitworth (Metal Industries) Limited, Gateshead-upon-Tyne, explains the superiority of spheroidal-graphite iron castings over castings in normal grey iron, the weakness of the latter being due to the flake formation of the graphite. The strength of spheroidal-graphite cast iron as cast is stated to be about double that of high-duty flake-graphite iron, and in the annealed condition it is said to have an elongation of 10-15 per cent.

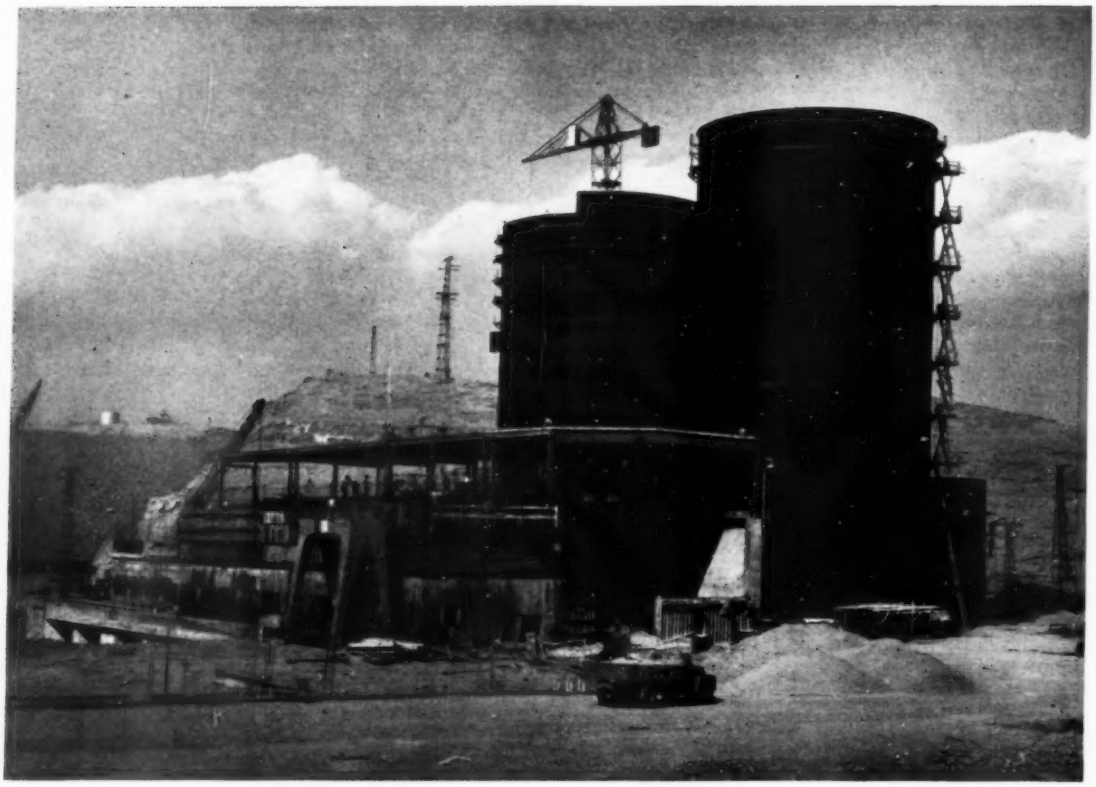


Fig. 1. Seyhan power house and surge tanks under construction

Seyhan Project, Turkey

The Republic of Turkey has undertaken a programme of river basin development designed to make the country stronger economically and improve the standard of living through control of floods, production of electric energy, and irrigation of semi-arid lands

At present, in Turkey, there are five multi-purpose projects under construction in five different river basins. The project described in this article is at Seyhan, on the river of the same name, and is located about 8 km. upstream from the city of Adana in south-eastern portion of the Republic.

Seyhan is a multi-purpose project for irrigation, flood control and power development. The project includes:

(*a*) An earth dam 50 m. in height above the river bed and 73 m. in height above the bottom of the cut-off trench. The dam is about 1,949 m. long and impounds 1,200 million cu. m. of water, of which about 925 million cu. m. are usable.

(*b*) A power house with space for three hydro-electric units of 18,000 kW each, of which two will be installed initially.

(*c*) A tunnel 8 m. in diameter and approximately 570 m. long which serves the power house and two irrigation outlets. The tunnel is controlled at the inlet by two 3·26 × 9·35 m. gates.

(*d*) A spillway controlled by six 7 × 6 m. radial gates which will discharge normal floods up to 1,200 cu. m. per sec. through a concrete paved channel terminating in a flip bucket at the lower end. Should floods greater than 1,200 cu. m. per sec. occur coincident with a full reservoir, the excess flow will be discharged over an uncontrolled emergency spillway which has a capacity of up to 5,100 cu. m. per sec.

(*e*) A 69 kV transmission line from the power plant to the cities of Adana, Tarsus and Mersin.

A general plan of the dam, power house and appurtenances is given in Fig. 4 and a vicinity map and plan of the transmission lines in Fig. 2.

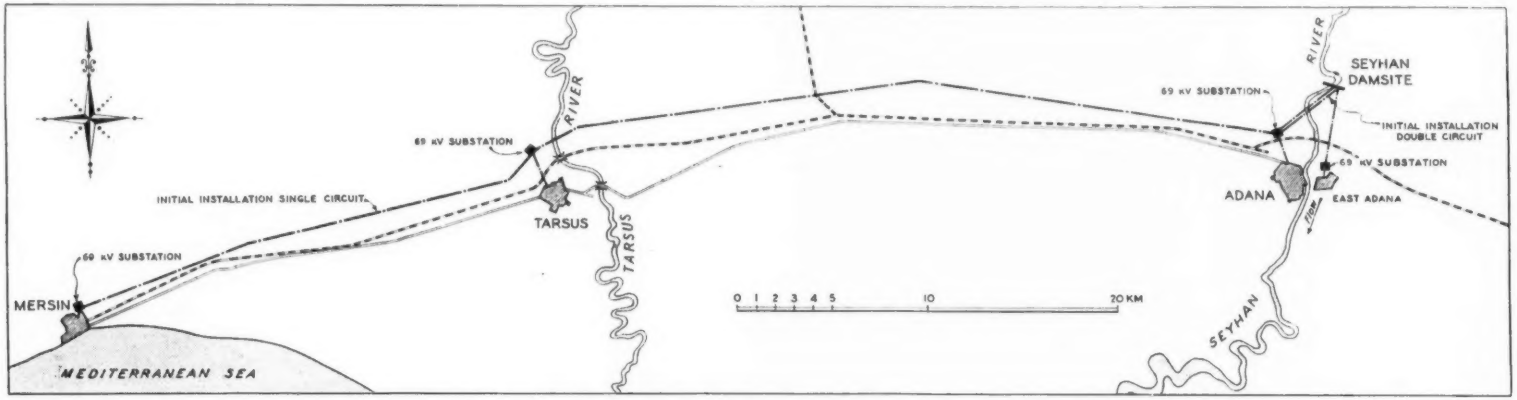


Fig. 2. Map showing electrical transmission system from Seyhan station

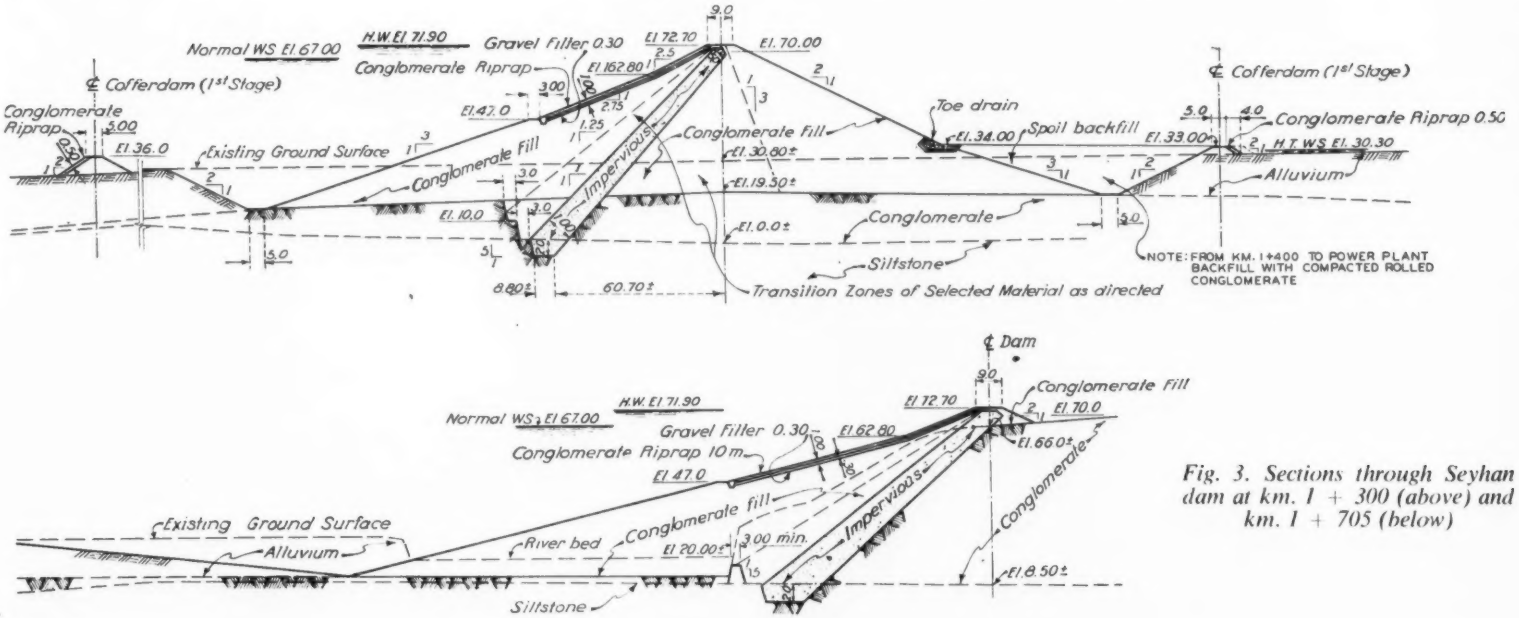


Fig. 3. Sections through Seyhan dam at km. 1 + 300 (above) and km. 1 + 705 (below)

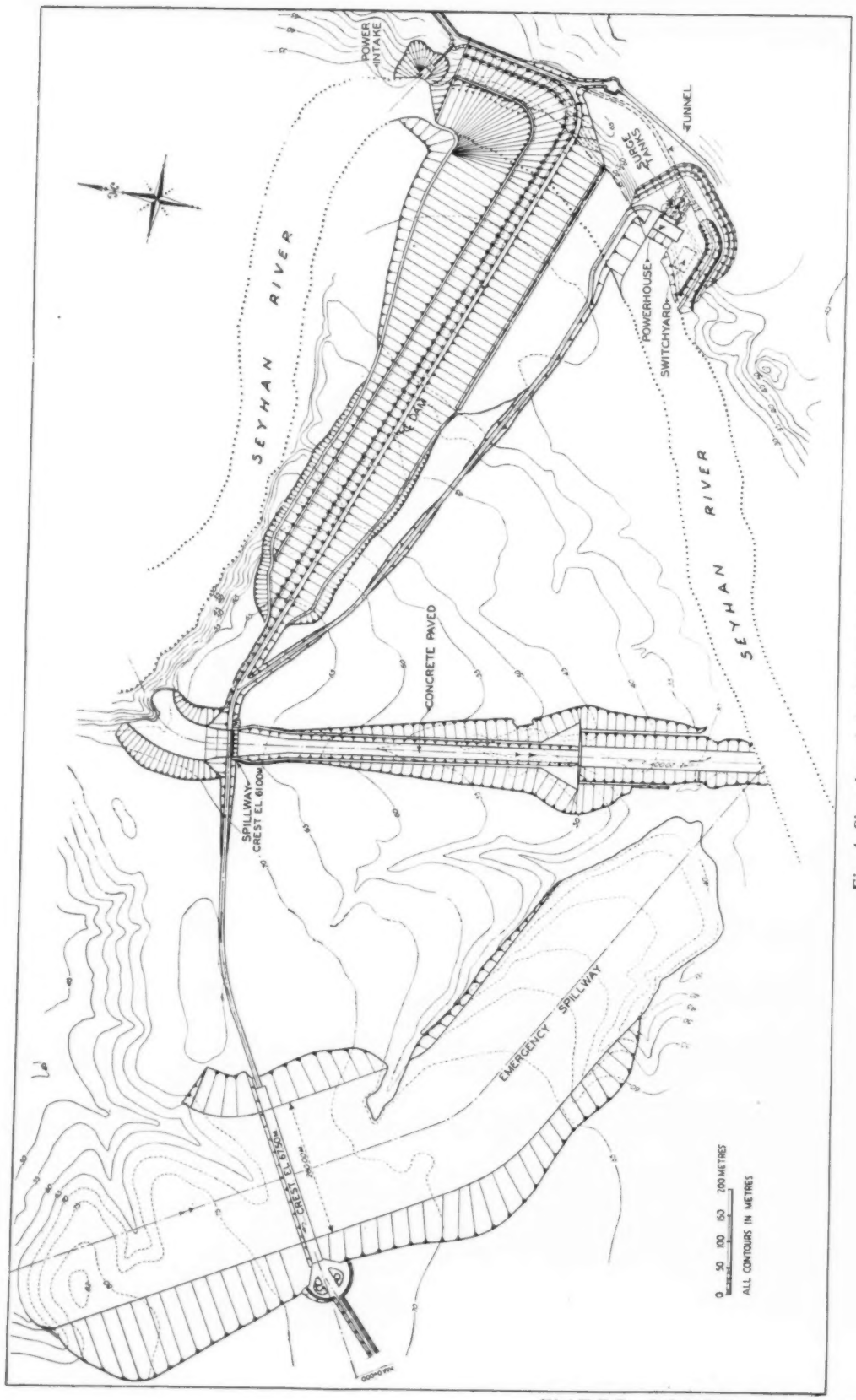


Fig. 4. Site plan of the Seyhan development

The Seyhan dam is located at the head of the alluvial plain of the Seyhan river. The drainage area above the dam is about 19,000 sq. km. The abutments of the dam are formed of variable stratum of non-uniform conglomerate which varies from cemented, to weathered, to loose. This conglomerate overlies a deposit of Miocene clay of very great depth. The surface of the Miocene at the dam site is encountered at elevations varying from 0 in the river valley to about 23 m. above sea level at the abutments. During the sub-surface investigations it was found that the conglomerate generally was pervious with wide variations in permeability depending upon the degree of cementation. The contact zone between the conglomerate and Miocene clay was found to be very pervious. These findings were substantiated during construction. On the right abutment the conglomerate is covered by a residual red clay; in the river valley by a bed of clean gravel which in turn is overlain by alluvial deposits, and on the left abutment the conglomerate rises steeply and there is no overburden.

The two greatest floods on record during the period of observation beginning in 1927, were those of December, 1936, and February, 1948. The 1936 flood had a single peak of 2,590 cu. m. per sec. and the 1948 flood had two peaks of 1,490 and 1,900 cu. m. per sec. respectively.

For reservoir design purposes, these discharges were increased by 25 per cent. with a similar increase in volume for the same flood duration. In routing these floods through the reservoir, it was found that with normal gate operation, the 1948 flood plus 25 per cent. was more critical, and that with unscheduled gate operation, the 1936 flood plus 25 per cent. was more critical.

These reservoir design floods were assumed to be the maximum floods that could reasonably be expected to occur during the life of the project. It was required that all features of the project would be safe with these floods and that the total discharge with normal operation would not exceed the safe carrying capacity of about 1,200 cu. m. per sec. for the downstream channel.

The spillway design flood was determined through a study of other river basins having characteristics, both hydrologic and topographic, similar to the Seyhan. From this study, a peak discharge for the spillway design flood of 6,700 cu. m. per sec. and a total run-off volume of 128 mm. was determined. This flood, about 2·7 times the maximum on record, was assumed to be the maximum possible flood that could occur over a much longer period than the life of the project, and it was assumed that it could occur under the worst combination of circumstances with the reservoir filled to the maximum power pool elevation. Under these conditions, the emergency spillway was required to have sufficient capacity to pass this flood without overtopping the dam. The peak outflow of this flood so passed through the spillways is 5,900 cu. m. per sec.

The dam is composed of three different sections in order to prevent excessive loss of water through the pervious conglomerate overlying the Miocene strata. On the right abutment the embankment consists of a vertical impervious core with pervious shells on the up and downstream side. In the river valley the dam embankment consists of a thin inclined impervious core supported by the pervious up and downstream sections as shown in Fig. 3 (section at station 1/300). On the left abutment the impervious core was placed directly against the pervious conglomerate with a pervious upstream section as shown in Fig. 3 (section at station 1/705). On the right abutment the impervious core extends down to sound conglomerate and from

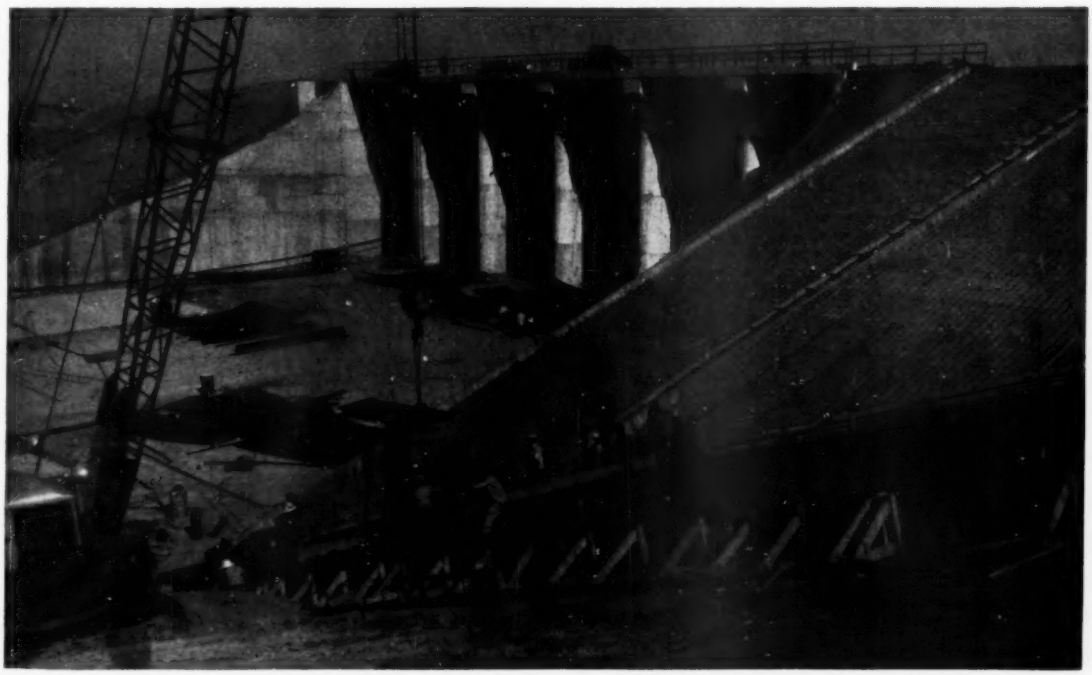


Fig. 5. The concrete spillway under construction

station 0/600 to 1/100, the residual red clay forms an impervious horizontal blanket between the core and the top of the river bank. The pervious conglomerate between the top of the river bank and the Miocene clay at about elevation 23 m. was blanketed with impervious fill. In the river valley from approximately station 0/800 to the end of the dam at station 1/955 the impervious core was carried in a cut-off trench down to Miocene.

As the left abutment is not massive and the conglomerate above the Miocene is devoid of cover and is pervious, the dam was curved so as to blanket the left abutment to a point downstream from the tunnel inlet.

To intercept seepage and relieve uplift drainage, relief wells were provided on the right abutment and a drainage blanket on the left abutment. In addition, a toe drain was provided as shown on Fig. 2 to intercept seepage through the embankment.

The 8 m. diameter tunnel is driven through the conglomerate forming the left abutment. Although the conglomerate was non-uniform, only two short sections required supports. The tunnel was lined with concrete throughout, which is not reinforced in the upstream position where the internal and external hydrostatic pressures are equal. The remainder of the lining is reinforced and at the lower end, where the overburden is not sufficient to provide the needed weight, a steel liner was placed. The steel liner extends beyond the tunnel and terminates in the three penstocks serving the power house and the two irrigation outlet valves.

The power house is of the indoor type and is a concrete structure 56 m. long by 27 m. wide with administrative offices enclosed. The power house and surge tanks are shown in Fig. 1. The turbines are vertical-shaft single-runner Francis type, rated at 27,500 h.p. at 32 m. net head and a speed of 125 r.p.m. Each turbine receives water from the tunnel through a 5·25 penstock and is provided with a 19·5 m. diameter by 40·5 m. high steel surge tank of the differential type. Butterfly valves remotely controlled and hydraulically operated are provided between the penstocks and turbine scrollcase extensions. The valves are inside the power house and accessible to the power-house crane.

Draft-tube gates are of the vertical-lift slide type, 5·7 m. wide by 5·5 m. high, and are handled by a 20 ton gantry crane operating along the draft-tube deck outside of the power house.

The generators are 13,800 V, three-phase, 50 cycle, 22,500 kVA, 0·8 power factor, 60° C. rise machines. Each generator is provided with differential overcurrent and earth-fault protection as well as overspeed and automatic carbon-dioxide fire-protection systems.

Connection to the 69 kV switchyard bus is by three-phase transformers, one for each unit, with ratings of 16,000 kVA when self cooled, 21,333 kVA when forced-air cooled and 26,600 kVA when forced-air and forced-oil cooled. The transformers are oil immersed, inert-gas filled and have an impedance of 7·5 per cent.

A travelling bridge crane is provided in the power house with one hoist of 135 tons and an auxiliary hoist of 25 tons.

The power station is manually operated with automatic controls and warning and protective devices, and is provided with conventional station service regular and emergency equipment, fire protection, lighting, telephone system, heating and air-conditioning, oil-treatment and compressed-air equipment.

The switchyard is located south of the power house and has six 69 kV bays, three for the main power transformers and three for transmission lines. All 69 kV circuit breakers are 1,200 MVA, 800 A air-blast type and those for the transmission lines are arranged for automatic reclosing. Three-pole manually operated 800 A isolating switches are used on both sides of all circuit breakers to permit inspection and maintenance.

Transmission to the West Adana, Tarsus and Mersin 69 kV substations is by double-circuit three-phase lines carried on steel towers, with two overhead

Fig. 6 (above). Panoramic view of the Seyhan development, showing, from left to right, power intake, dam under construction and power house

Fig. 7. (right). View of power house from the tailrace

Fig. 8 (right). Closure section of the dam under construction

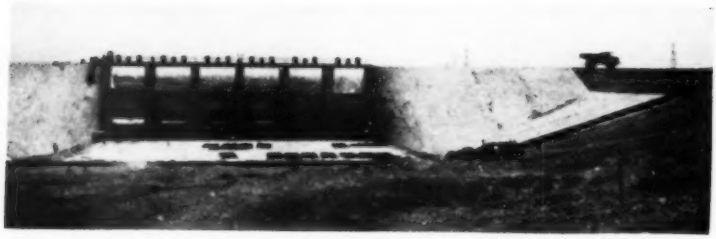


Fig. 9. Gates and bridge from spillway intake

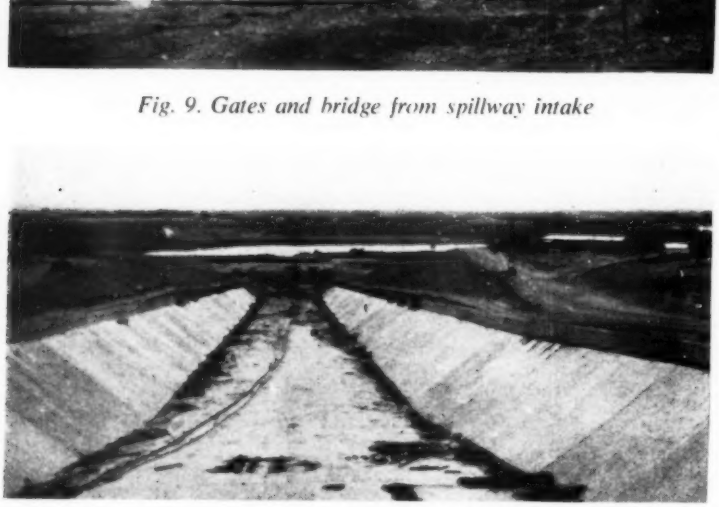


Fig. 10. View of spillway channel from bridge

earthing wires. The second circuit and second overhead earthing wire from West Adana to Mersin will be installed later. The transmission line to East Adana and Incirlik substations is single-circuit three-phase and is carried on steel towers with one overhead earthing wire.

The 69 kV substations step down to 15,000 V for the industrial networks and 6,300 V for the existing city distribution systems.

The gated spillway shown in Fig. 5 has been designed to pass (a) 1,170 cu. m. per sec., which would occur with the 1948 plus 25 per cent., and at the beginning of the flood all gates are open and the water surface in the reservoir is at elevation 61; (b) 1,640 cu. m. per sec. which would occur with the 1936 plus 25 per cent., and at the beginning of the flood the water-surface elevation in the reservoir is at elevation 67 and the gates are closed and do not begin to open until the water surface rises above elevation 67; (c) 2,500 cu. m. per sec. for the spillway design flood with conditions as in (b) above.

The emergency spillway capacity is 3,400 cu. m. per sec. with normal operation and 5,100 cu. m. per sec. with emergency operation. This spillway is an uncontrolled ogee weir with crest at elevation 67·5. With all gates of the gated spillway operating, the freeboard below the top of the dam (elevation 72·7) will be 1·8 m. With the spillway gates unoperative, the freeboard will be 0·8 m. under maximum conditions.

The diversion of the river was accomplished in two stages. In the first stage the diversion channel was excavated across the bend in the river at approximately station 1/200. The first-stage cofferdam was constructed on the left side of this channel and the area between the cofferdam and the left abutment was unwatered and construction of the dam, tunnels and power house initiated. On the right of the diversion channel no cofferdam was required as the area is above normal river level.

When the tunnel was completed and the penstock bulkheads put in place the river was diverted through the tunnel and the second-stage cofferdams were constructed across the diversion channel both up and downstream. The area in the centre of the dam within the second-stage cofferdam was then unwatered, the cut-off trench carried down to the Miocene clay, and the embankment placed in the closure section. A general view at this stage of the construction is shown in Fig. 8.

The unwatering of the foundation area in both cofferdams presented no serious problems despite the pervious character of the conglomerate and of the contact zone between the conglomerate and the Miocene clay. The principal reason for this was that at the site the level of the river is controlled by a diversion dam downstream. When the diversion dam is opened the elevation of the water surface at the Seyhan site is approximately 22 m. high, but when it is closed the water-surface elevation is approximately 31 m. The pool thus formed by closing the diversion dam caused silt to be deposited from the Seyhan river in the vicinity of the Seyhan dam and this natural blanket, which was deposited in the diversion channel and along the cofferdams, reduced seepage into the working areas.

The reservoir-operation schedule is considerably influenced by the flood season, which on the Seyhan river occurs during the period from November 1 to March 31. During this period, the maximum reservoir level will be at elevation 61 to provide sufficient flood-control storage. The period from March 31 to May 1 will be used to increase the storage in the reservoir to satisfy power demands and irrigation requirements for an area of 144,000 hectares. From May 1 to September 30, the reservoir will be held at a maximum level of elevation 67.

Principal quantities of material involved in the construction of the Seyhan dam are as follows:—

Cofferdams	336,000	cu. m.
Stripping	600,000	,, ,,
Excavation, Dam Foundation	3,300,000	,, ,,
Excavation, Core Trench	540,000	,, ,,
Excavation, Spillway	1,100,000	,, ,,
Excavation, Emergency Spillway	2,300,000	,, ,,
Excavation Intake, Power-house Tailrace	800,000	,, ,,
Embankment, Impervious	830,000	,, ,,
Embankment, Pervious	6,200,000	,, ,,
Filters	51,000	,, ,,
Concrete, Gated Spillway	35,000	,, ,,
Concrete, Tunnel Lining	11,000	,, ,,
Concrete, Power House	20,000	,, ,,
Reinforced Steel	4,200	metric tons
Steel—Penstocks, surge tanks, tunnel liner	1,000	,, ,,

The construction equipment used on the Seyhan dam is owned by the Turkish Government and operated by the contractor. Most of the construction equipment, particularly the excavation, earth-moving and concreting equipment, is of United States manufacture. The remainder was obtained from Britain and Europe. The permanent equipment comes largely from Germany, France, Italy and Austria. The cement was obtained from Greece, where it was manufactured to British standards for ordinary Portland cement with a total equivalent alkali content of not over 0·6 per cent.

The Seyhan project is financed in part by a loan from the International Bank for Reconstruction and Development and in part by the Turkish Government and private funds. The private Turkish funds subscribed constitute at least 51 per cent. of the stock of the agency established to operate the power features.

The Seyhan project is being executed by the Dams Division of the Devlet Su Isleri of the Ministry of Public Works. The Devlet Su Isleri is headed by Suleyman Demirel and the Dams Division by Kutlu Buyukdoluca.

Construction of the project was initiated in November, 1952, with the selection of Knappen-Tippetts-Abbett-McCarthy as Consulting Engineers. Calls for tenders for furnishing construction equipment were issued in December, 1952, and January, 1953, and for constructing the dam, power house and appurtenant works in April, 1953. Calls for tenders for furnishing permanent equipment were issued at intervals thereafter as required to keep pace with the overall construction programme. The construction contract was awarded to Morrison-Knudsen and Garanti Insaat, a joint venture, in July, 1953. The first-stage diversion was effected on December 19, 1953, and final, or second-stage diversion, on April 21, 1955. Final completion of the project is scheduled for June, 1956, with the first unit expected to be placed on the line on April 1, 1956. The estimated cost of the project, including lands, rights of way and relocation of highways in the reservoir area is T.L. 149,000,000.

An article on the Hirfanli project in Turkey, which is being undertaken jointly by George Wimpey and Co. Ltd. and The English Electric Co. Ltd., will appear in a later issue.

New Safety Helmet

A new model of the MSA Shockgard safety helmet, redesigned to give even greater protection, has been introduced by the Mine Safety Appliances Company of Pittsburgh, Pa. Dielectrically tested at 15,000 V for one minute, it is claimed to show less than eight milliamperes leakage, and to withstand a 40 ft.-lb. impact without losing any of its dielectric strength. It is made, from a specially-formulated plastic material, in yellow and grey, and has no metal parts. Like the previous Shockgard models, the new helmet is impervious to oil, grease, and most chemicals, and offers effective protection over a large temperature range—25° below and 160° above zero on the Fahrenheit scale. It meets all of the specifications under Schedule Number AP-1 established by the Edison Electric Institute, and is fitted with a replaceable snap-in suspension which allows for adjustment to fit a full range of head sizes. Winter liners and chin straps are available.

Admiralty Underwater Hydrodynamics Laboratory

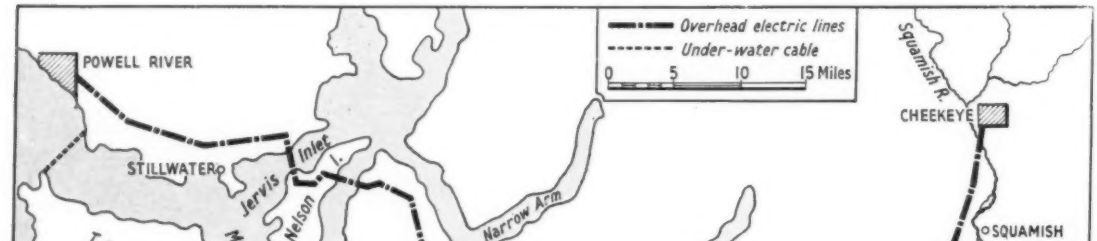
New laboratories have recently been inaugurated by the British Admiralty at Teddington to investigate problems relating to the movement of bodies at high speed under water. There is a great deal to be learned in this field of underwater hydrodynamics, and the laboratories are believed to contain apparatus that is not to be found anywhere else in the world. The outstanding item of equipment is a 60 ton high-speed rotating beam which draws bodies under test through an annular channel, and in addition there are two water tunnels similar to the wind tunnels used for aeronautical research. All this equipment is of a size to permit full-scale tests.

The main building contractors were Richard Costain Limited, the mechanical engineering was carried out by Costain-John Brown Limited, and the electrical engineering by The English Electric Co. Ltd.

Holman Drills at Kariba. Among other Holman equipment, 50 rock-drills have been ordered by civil-engineering contractors engaged on the first stage of the Kariba Gorge hydro-electric scheme on the Zambesi, Southern Rhodesia. Equipment has already been supplied from the company's factory, and branches in Southern Africa. Stage one of the contract, which includes two cofferdams and a large diameter diversion tunnel, is now let to a consortium comprising The Cementation Co. Ltd., and John Laing & Son Ltd.

Power Crossing in British Columbia

B.C. Electric is planning one of the longest power-line crossings in the world in a line from Cheekeye station to Powell River Company and township



THE accompanying map shows the route of a new 132 kV overhead transmission line between Cheekeye and Power River which B.C. Electric hope to have in operation by next October. In addition to Powell River Company and township, the line will serve Westview, Cranberry, Wildwood, Woodfibre, Port Mellon and the Malaspina Peninsula, as well as other communities between Powell River and Squamish, and will have the effect of ending the power restrictions of the last few years.

From an engineering point of view the outstanding feature will be the overhead crossing of Jervis Inlet. It will be one of the longest crossings in the world, exceeded, possibly, only by Messina, and will consist of four steel cables, each 1¼ in. in diameter and 10,100 ft. long, strung between anchor towers, the north, mainland, tower being located at the 1,600 ft. level. The towers will each be about 70 ft. high and are scheduled to be installed in April, cables being strung in June or July.

B.C. Electric engineers decided on an overhead, rather than underwater, cable because of heavy tidal currents and the rough and rocky bottom of Jervis Inlet. These conditions contrast sharply with the sandy bottom and gentle tidal flow found in the Gulf of Georgia, which the company will span this year with underwater cables to Vancouver Island. Indeed, according to Mr. Tom Ingledow, Vice-President and Executive Engineer of B.C. Electric, an underwater crossing of Jervis Inlet would cost at least as much as an overhead structure and would not offer as much security of service.

A second crossing, similar in design and measuring 6,500 ft. long, will be constructed over Agamemnon Channel to the east of Jervis Inlet.

The line will cost well over $3,000,000 of which $600,000 will be required for the Jervis Inlet crossing. Substations at various points in the line will cost another $2,000,000.

Initial survey work has been completed, the right-of-way has been staked out and clearance well advanced, pole placing has been commenced at the Powell River end, roads are being built through the coastline wilderness to the tower sites, and surveys are in progress for the tower footings and water crossings. Work is also continuing apace on the reinforcement of distribution services serving Powell River and other centres in preparation for the considerably higher load they will have to carry.

A particular problem is presented by the fact that the B.C. Electric frequency is 60 c.p.s. whereas that at Powell River is 50 c.p.s., and a 20 MW frequency changer is being installed at Powell River.

Plans are being made to install an underwater cable from the mainland to Texada Island, as shown dotted on the map, and the town of Lund, 11½ miles northwest of Powell River, will be served by an extension line by the autumn of 1957.

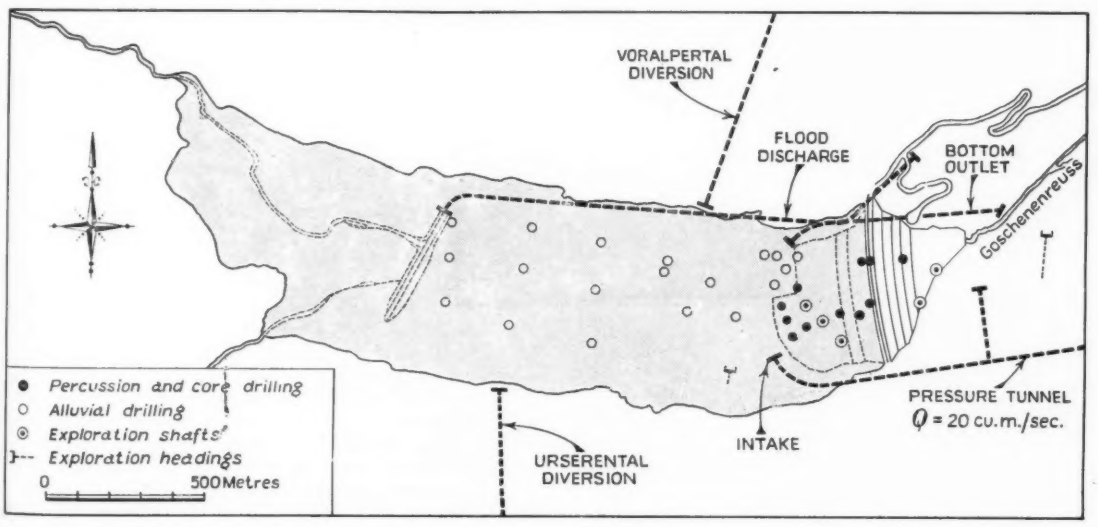
Abstracts from the World Technical Press

Göschenalp Development

A description is given of the installations of this development which will utilise the power resources of the Dammereuss and Chelenreuss rivers between the Göschenalp and the township of Göschenen, as also the waters of the Voralper valley and of the back stretch of the Urseren valley. The project of the Göschenalp rockfill dam (WATER POWER, February, 1955, p. 79-80) was worked out on the basis of extensive borings shown in the plan appended. Special attention was devoted to the imperviousness of the core (fine sand and up to 10 mm. size gravel with an addition of 4 per cent. bentonit or 16 per cent. Opalinus clay), which will be sunk right down to the rock, and will have a filtering layer on both sides. The bottom outlet on the left slope of the valley, designed for a discharge of 100 cu. m. per second, will be supplemented by a diversion tunnel, in order to keep the bottom of the valley dry while work is in progress. Also on the same slope there will be a flood-discharge gallery with a capacity of 200 cu. m. per sec. which corresponds to a flood discharge of 4·7 cu. m. per sec. per sq. km. of catchment. The intake will be on the right slope, immediately above the foot of the dam. The 6·8 km. long power tunnel will have a diameter of 2·7 m. The two-chamber surge tank, with intermediate inclined shaft, will be able to cope with the inflow at any pressure oscillation. A steel-lined pressure shaft, 2·1 m. diameter and 1,070 m. long, will lead from the surge tank to the underground power house excavated under the right slope. The power house will be safely protected from flooding, in the case of a burst in the short pipe connection between pressure shaft and turbines, by means of an overflow gallery laid at a considerable depth and discharging into the Göschenreuss compensation reservoir of the Wassen plant. The 140 MW Göschenen power house will be equipped with four vertical generating sets, each driven by a Pelton wheel, two of the sets to supply single-phase current to the Federal Railways, and the other two to feed the system of the Central Switzerland Power Works with three-phase current. The transformers will be housed in separate underground cubicles. Owing to the dual-supply layout of the plant, the single-phase 66 kV energy will be transmitted by cables to the Göhschenen substation of the railways, while the three-phase energy, stepped up to 150 kV, will go to the open-air switchyard for which a convenient site has been found 300 m. south-west of the Göschenen road bridge on the right bank of the Göschenenreuss Upon completion, and in a year of average discharge, the Göschenen plant will produce 320 million kWh, of which 43 per cent. will be generated in the six winter months. In addition, the water available in winter will enable the Wassen and Amsteg plants downstream to increase their production by 100 million kWh. (W. Eggenberger, Zurich, *Bulletin de l'Association Suisse des Electriciens*, Vol. 46, No. 16, 6.8.1955, p. 725, 4 pp., 4 ff.)

Viaur-Tarn Development

This new EDF development, which combines generation and storage pumping, is to operate non-stop during the months of November and December only, and to feed the Paris network at peak hours during the rest of the year. It links the Viaur, a tributary of the Aveyron, with the Tarn 16·8 miles to the south, one of the major tributaries of the Garonne. Roughly speaking, the system is based on a short-cut diversion of the Viaur into the Tarn, the Aveyron itself flowing into the Tarn much farther to the west. Viaur river waters are dammed at Salars Bridge, and moved from the reservoir through a one-mile tunnel to Bage, where Bage river waters are also dammed. Water is then pumped to Pareloup, four miles away and 260 ft. higher, and then flows through a seven-mile tunnel to Alrance, 240 ft. lower, to supply a 11,500 kW station. The Alrance turbine discharges direct into the Villefranche de Panat reservoir from which a three-mile tunnel connects with St. Amans reservoir, which acts as a surge tank. The water finally



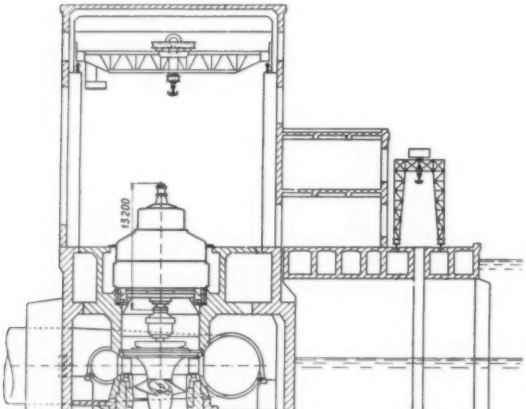
falls 1,640 ft. through a 3,600 ft. penstock to supply the Pouget station which consists of three 42,000 kVA vertical alternators driven by Alsthom Pelton wheels, and has a total capacity of 115,000 kW. This development is conspicuous by its flexibility. In case of a failure in the Paris network, all the installations go into operation within 30 seconds, and power is re-established 500 miles away. The system's annual output, 300 million kWh, though no more than 2 per cent. of France's hydro-electric output, increases the country's stored water power by 20 per cent. (*Esso Oilways*, Vol. 7, No. 4, 1955, p. 12, 4 pp., 10 ff.)

Valle di Cadore Dam

This double-curvature arch dam is part of the Piave-Boite-Maè-Vajont development of the SADE concern. In addition to a detailed description of the dam and its ancillary works and of the grouting procedure adopted, the design criteria of the structure are discussed, and a table gives the stress values arrived at by various methods of computation. The construction plant is also described, and the article concludes with an account of the construction methods applied. (Dott.Ing. Egidio Indri, *L'Energia Elettrica*, Vol. XXXII, No. 3, March, 1955, p. 213, 18 pp., 16 ff.)

Oerlikon Alternator for Aswan

This article deals with some of the problems encountered in designing two generators of uncommon size and weight supplied for the Aswan power station on the Nile. The heaviest ever manufactured at Oerlikon, these generators will be driven by directly coupled Kaplan turbines of Escher-Wyss design; they will have an output of 49,500 kVA each, their rated speed being no more than 100 r.p.m. while the runaway speed, 345 r.p.m., is exceptionally high. With a diameter of 24 ft. 3 in., the rotor retains a peripheral velocity of 445 ft. per second at runaway speed. A special well-tried Oerlikon rotor design meets these strenuous conditions. The thrust bearings had to be designed for a total load of 1,500 tons. The alternators



are of the totally enclosed type with air recirculation, and the stators are sunk into the floor, the only visible parts of the machines being the exciters and permanent-magnet generators 14 ft. 9 in. in height. The diameter of the pit is 39 ft. 6 in., and the total height of the alternator between the face of the coupling and the top of the pilot exciter is 43 ft. 3 in. (Dr. H. Roose, *Bulletin Oerlikon*, Vol. XXXIV, No. 306, Oct., 1954, p. 87, 4 pp., 4 ff.)

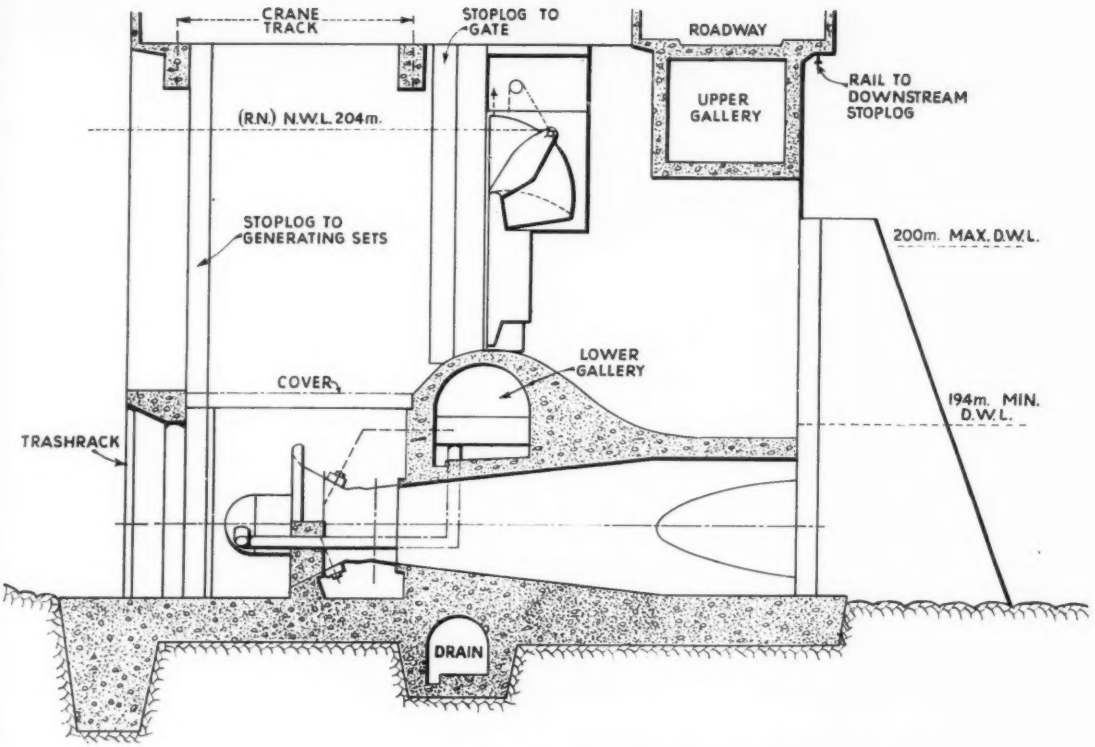
Mettlen Substation

This article describes in detail the three 100 MVA transformer banks installed at Mettlen, the first major 220 kV substation in Switzerland, which connects several important 150 kV systems to the 220 kV transmission line running north to south over the Alps. The transformers, three units to each bank, are designed from the regulation aspect, to cope with the very severe conditions laid down by the customer. (A. Danz, *The Brown Boveri Review*, Vol. 41, No. 8, August, 1954, p. 271, 9 pp., 10 ff.)

NOTE. The above issue also contains a description of the 220 kV air-blast circuit breakers installed at the Mettlen and Lavorgo substations, pp. 311/312, 3 ff.)

Castet Power Units

This paper, read at a meeting of the Société Française des Electriciens, examines the possibility of extending the application of submerged Castet-type power units (WATER POWER, October, 1954, p. 403) to large low-head run-of-river or tidal plants. The main advantages of these units lie in the small space as well as the reduced substructure and concrete framework they require. In traditional installations, a 6 m. diameter wheel leads to an equipment taking up a power-house length of 20 m., whereas four 3 m. diameter wheels, generating the same amount of power would require over 40 m., and six 3 m. diameter units 60 m.; in a Castet-type plant, four units would require no more than 24 m., and nine no more than 36 m. An even greater advantage is that submerged units need no superstructure, so that it is easy to fit in above them the flood-control sluices or, in the case of tidal plants, the gates controlling the water levels; besides, the length of the power house does not add to that of the barrage, and this results in a substantial reduction of the volume of concrete necessary. A considerable increase of the number of generating units then becomes admissible; for instance, in a run-of-river plant, the length of 40 m. corresponding to a traditional 6 m. diameter unit and its gate, could accommodate up to eleven 1·8 m. diameter units, while the same length in a tidal plant, which involves gates of smaller size, could be filled by an equal number of 2·5 m. diameter units. In instances altogether free from gate problems, units of greater diameter would substantially reduce the length of the power house. Asynchronous generators are particularly indicated under such conditions: reactive power could then be provided by synchronous condensers, and it would be feasible to combine a 40 MVar condenser with a generating equipment of twenty 2 MW units. It is extimated that the price of the condensers and transformers would not exceed Fr. 5,000 or 5,500 per installed kW, i.e., about 2 per cent. of the price of a plant of the traditional type. Efficiency would be of the order of 95 per cent. for the generators, 92 per cent. for the turbines, and 85 per



cent. for the sets, taking into account a 2 per cent. loss in the synchronous condensers. Compared to traditional units, this is a difference of no more than about 2 per cent. but it should be noted that a four months' reduction of the time taken by erection work is enough to offset the loss of one point of efficiency throughout 30 years. On the other hand, the total economy in capital expenditure is likely to exceed 40 per cent. owing above all to the substantial simplification of civil engineering work. The appended cross-section, taken from the project of a large-size submerged plant of the Castet type, shows to what extent concrete work can be reduced. (Jean Guimbal, *Bulletin de la Société Française des Electriciens*, Series 7, Vol. 5, No. 52, April 1955, p. 189, 7 pp., 5 ff.)

Thermal-Storage Heating for a Hydro-Station

This Swiss hydro-electric station of Gondo, near the Simplon pass, comprises an underground machine hall and a surface building containing the control room, workshops and stores. This building is heated by an electric boiler coupled to a thermal-storage tank and fed from the station auxiliary supply. Two 270 kVA 380 V sets, one acting as standby, provide the auxiliary power and also serve the villages of Gondo and Simplon. The arrangement is such that the boiler is supplied primarily by off-peak power during the night time. A temperature control on the boiler regulates the power to maintain the water temperature in the storage vessel at a predetermined value, but an overriding power regulator prevents the total load on the generating set from exceeding a given limit. Thus, during the daytime, precedence is automatically given to the auxiliary and local demands, the supply to the boiler being correspondingly reduced, when the heating system draws on the heat in the storage vessel. In this manner adequate building heating is combined with an economical loading of the auxiliary generator. (*The Brown Boveri Review*, Vol. 42, No. 3, March, 1955, p. 85, 2½ pp., 4 ff.)

Columbia River Developments

This is a condensed version of a 14,000-word report, published April 19, 1955, by the Water Resources Development Committee of the Trail Chamber of Commerce, of which the author is chairman. The Columbia River watershed covers an area of 260,000 sq. miles and in a normal year discharges into the sea 180 million acre ft. of water. Use of this water is circumscribed by three International Agreements: The 1846 Oregon Treaty and the 1909 Boundary Waters Treaty, both concluded between Great Britain and Canada, and the 1944 Columbia Reference, entered into between Canada and the United States. In addition to the Principles advanced in pursuance to the Boundary Waters Treaty and operations of the International Joint Commission, a new concept known as Downstream Benefit has come to the fore; this concept confers on a river development which stores water for its own use the right to a share in any increase in electrical power that rival installations downstream may be able to generate by virtue of such upstream storage. So far, no State Legislature has taken positive steps to establish this concept as a principle. Out of the 10 major projects which present possibilities of development in the foreseeable future, all involving diversion of the Upper Kootenay River

into Columbia Lake, the report discusses only the two that appear to have aroused the most conflicting arguments, Murphy Creek (350,000 h.p.) and Kaiser dam (300,000 h.p.), and reviews the benefit each scheme would bring to Canada and the U.S.A. respectively, laying particular stress on Kaiser dam as the bone of contention that has provoked the present intergovernmental controversy. The arguments of supporters and opponents of Kaiser dam are then listed and analysed. Canadian interests are especially concerned with the two Waneta plants on the Pend d'Oreille River, and the way their operation could be influenced by the five U.S. plants now operating on the river south of the boundary, among them Hungry Horse and Cabinet Gorge, to which will be added Box Canyon upon completion. In other words, it is feared that Canadian water in the Arrow Lakes could be used as an instrument for reducing or otherwise affecting production of Canadian power on the Pend d'Oreille River. It should also be noted that one of the arguments advanced against Kaiser dam is that it would better Kaiser's position vis-à-vis Kitimat in world aluminium markets. In his conclusion, the author advocates the insertion in any international agreement respecting storage of water, of clauses which would give Canada equal voice with the United States as to timing of controlled flow. (A. C. Ridgers, M.E.I.C., *The B.C. Professional Engineer*, Vol. 6, No. 6, June, 1955, p. 33, 5 pp., 2 ff.)

New Oerlikon Testing Plant

To enable circuit breakers to be tested for high tension and rupturing capacities occurring in present H.T. systems, the Oerlikon Engineering Company, Zürich, have built a new testing station to replace a former plant dating from 1933. This station is housed in two separate buildings; the machine room adjacent to the five test bays (two for 14 kV and three for 30 to 380 kV, and, facing the latter 76 ft. away, the observation building which gives a perfect view of the breakers under test. When completed, the station will be equipped with two short-circuit alternators with a total-making capacity of 3,000 MVA, a speed of 3,000 r.p.m., a maximum rated voltage of 14 kV, and a rated current of 3,500 A. The alternator, now in operation, was commissioned in May, 1954. (A. Gantenbein, *Bulletin Oerlikon*, Vol. XXXIV, No. 305, Aug., 1954, p. 55, 14 pp., 20 ff.)

Note: A separate article deals in detail with these short-circuit alternators (p. 69, 4 pp., 5 ff.).

Reinforced-Concrete Pressure Pipelines Made Impervious with Aluminium Foil

Considerable difficulty has always been encountered in making reinforced-concrete pressure pipelines, or the walls of reinforced-concrete hydraulic constructions, impervious under pressure. The method described has been successfully followed for pressure pipelines in hydro-electric plants and pump units. It is based on a simple principle. If even one thin layer of metal foil is applied with a suitable adhesive to a sufficiently strong concrete or reinforced-concrete slab, the latter will be droptight even under extremely high water pressure. In practice, the author adopted liners consisting of several layers of aluminium foil, in crossed strips or overlapping, each about a thousandth of an inch thick. The metal foil was laid on the reinforced-concrete wall of the pipeline without any pretreatment immediately after the falsework had been dismantled. Special bitumen-base or natural or synthetic-resin base adhesive mastics were used, both for the first and the successive layers, until the liner was completed. It was considered advisable to adopt multiple layers to obviate any eventual unevenness, or slight incidental tears, as well as to stagger the joints between single overlapping foils. However, the total final thickness of the liner was little more than 1/25 in. Over the aluminium foils a protective layer of wired concrete was placed. Pipelines provided with this thin liner proved impervious even at extremely high internal pressures, and remained so even where unforeseen causes or intentional excess test pressures produced visible cracks in the reinforced-concrete pipe. (A technical digest of the European Productivity Agency, O.E.E.C., Paris. L. Zaretti, "Impiego dell'alluminio nei rivestimenti impermeabilizzanti delle condotte forzate per impianti idroelettrici." *Alluminio 17* (1-2), 1948, 34-36; *24* (2), 1955, 152.)

Hydro-electric Developments in Brazil

Boletim Cemig (Bulletin of the Centrais Electricas de Minas Gerais S/A) gives an account of the activities of the Company in 1954. The Tronqueiras power station was put into service in the January, and the Itutinga plant, to be increased later from 34,000 to 63,000 h.p., followed in March. Work at Salto Grande made substantial progress, and the first construction stages, including the greatest tunnel ever built in Brazil, 4,600 m. long and 6·25 m. diameter, as well as the Guanhaes dam, were nearing completion. At Cajuru dam, inaugurated February 1, 1955, which creates an accumulation of 190 million cu. m. on the Rio Para, work was in progress on the 7,500 kW automatic power house. At Central Eléctrica do Piau, a subsidiary of CEMIG, the power house, designed for an ultimate capacity of 37,500 h.p. was also inaugurated in the February. Work on the Camargos dam and its power house on Rio Grande was expected to begin before the end of 1955. Other installations on the same river as well as in the Santo Antonio valley are comprised in the 1956 construction programme, and a further expansion of the latter development is contemplated. (*Revista Mineira de Engenharia*, Vol. XVII, No. 54, February, 1955, p. 55, 14 pp., 10 ff.)

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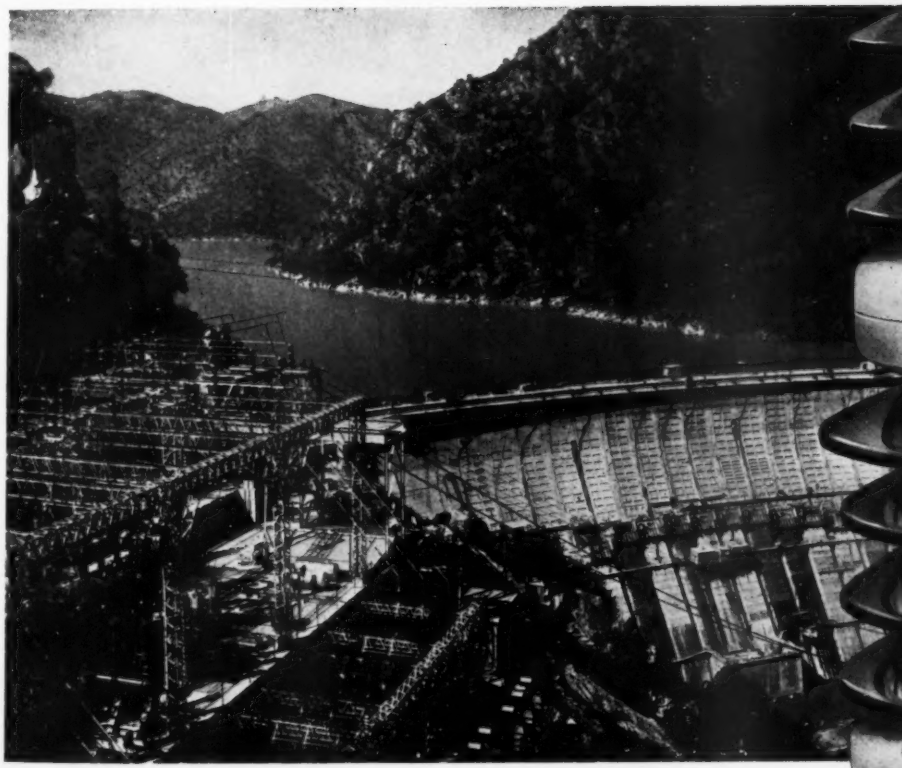

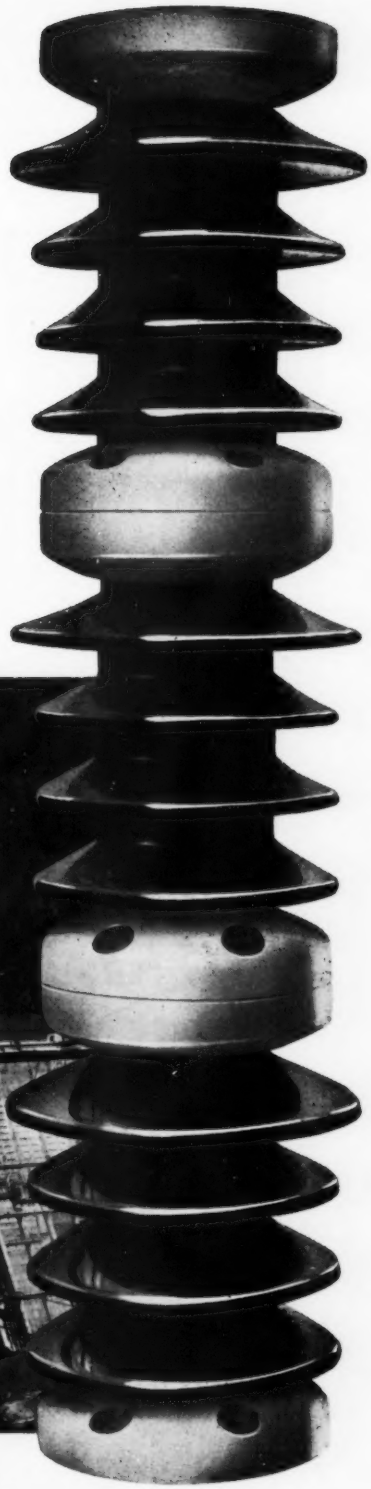

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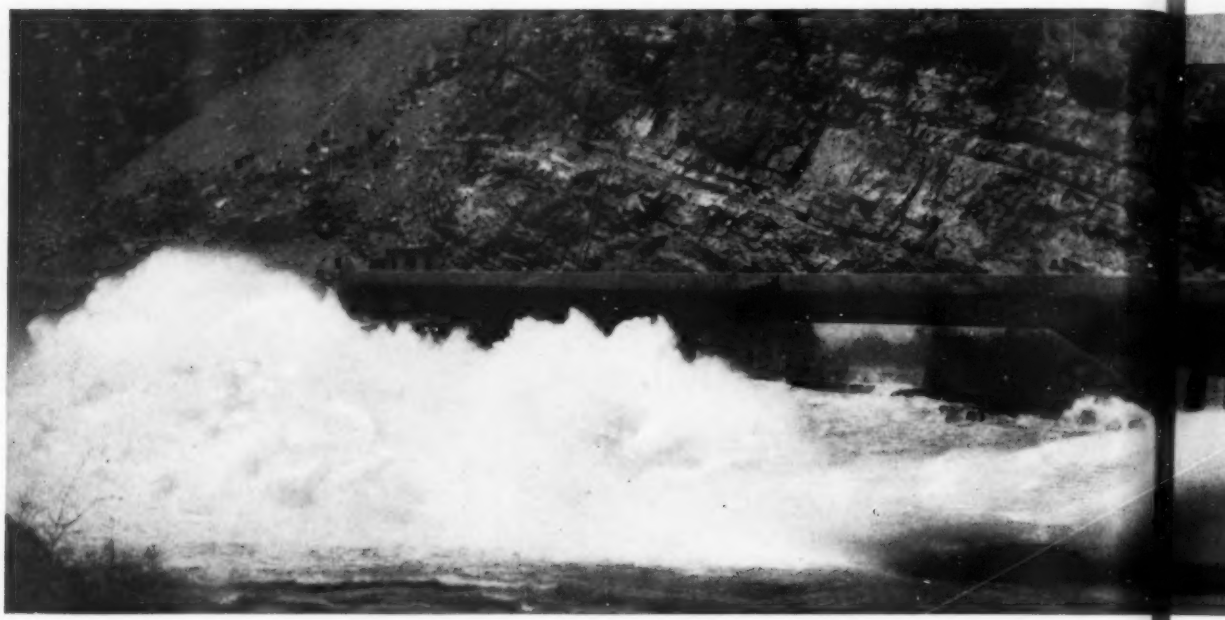

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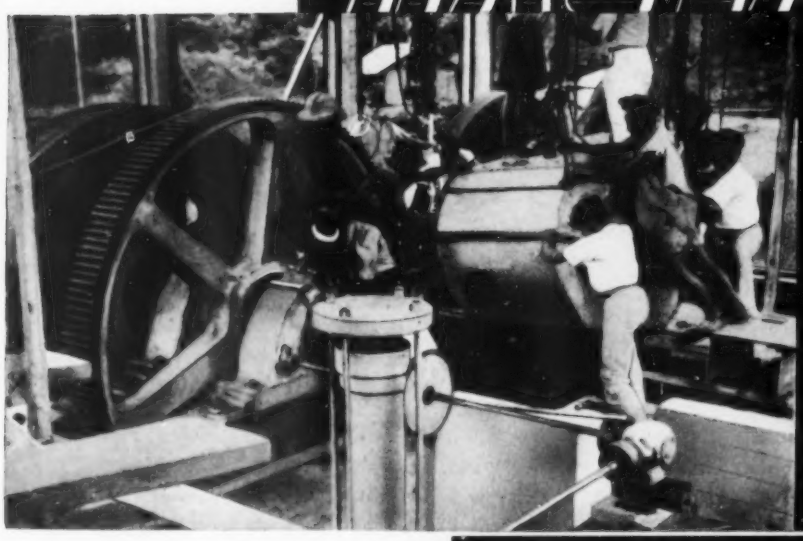

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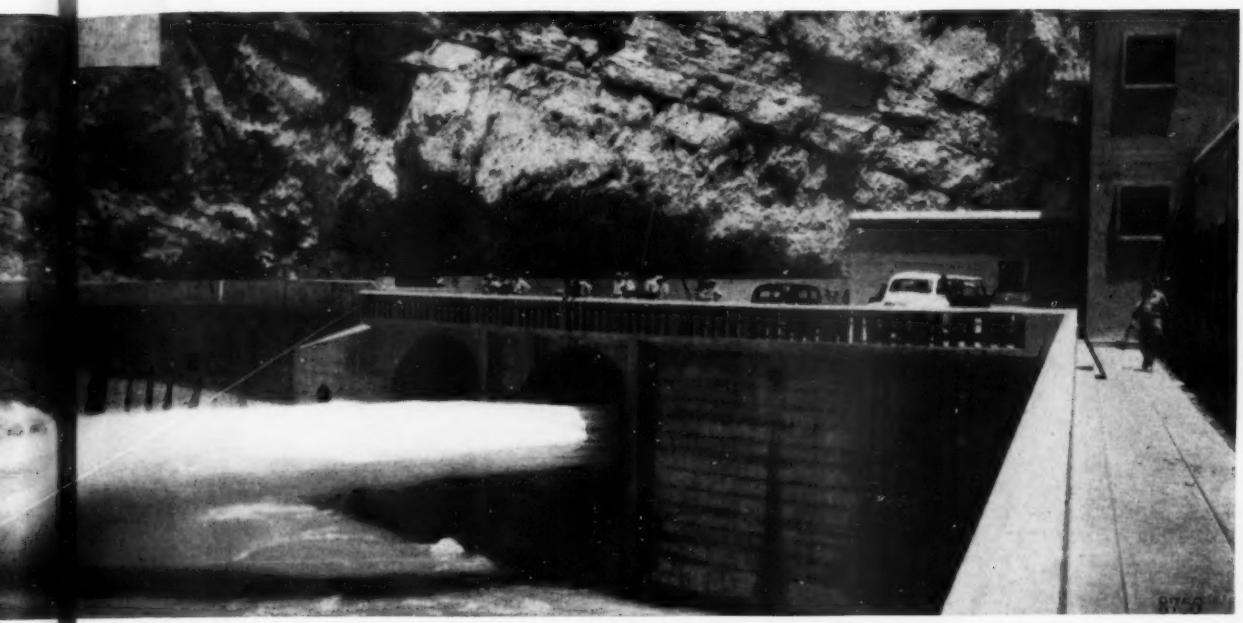

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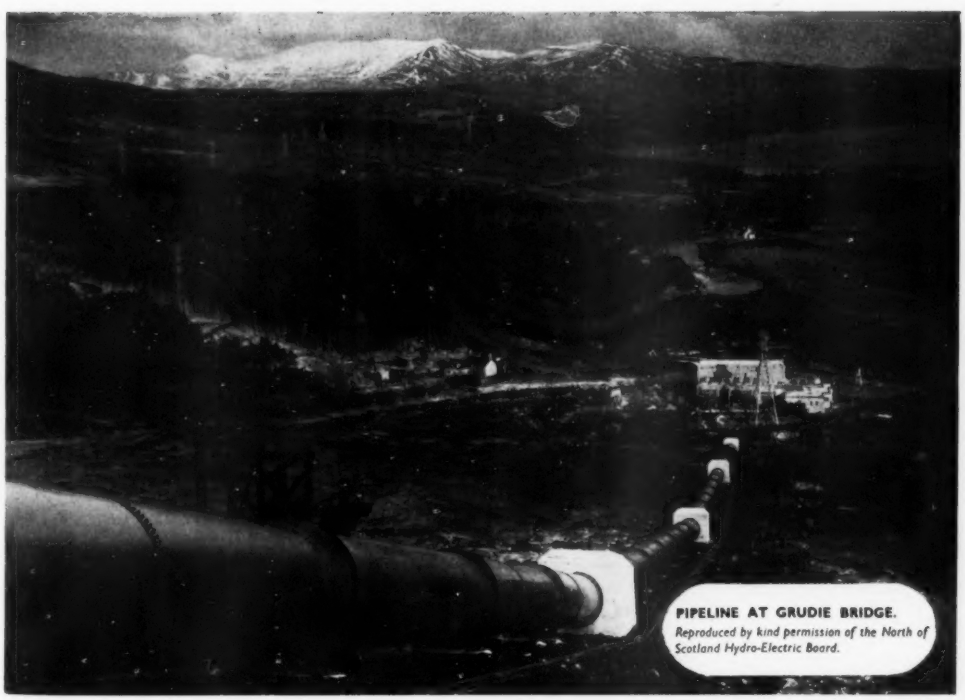

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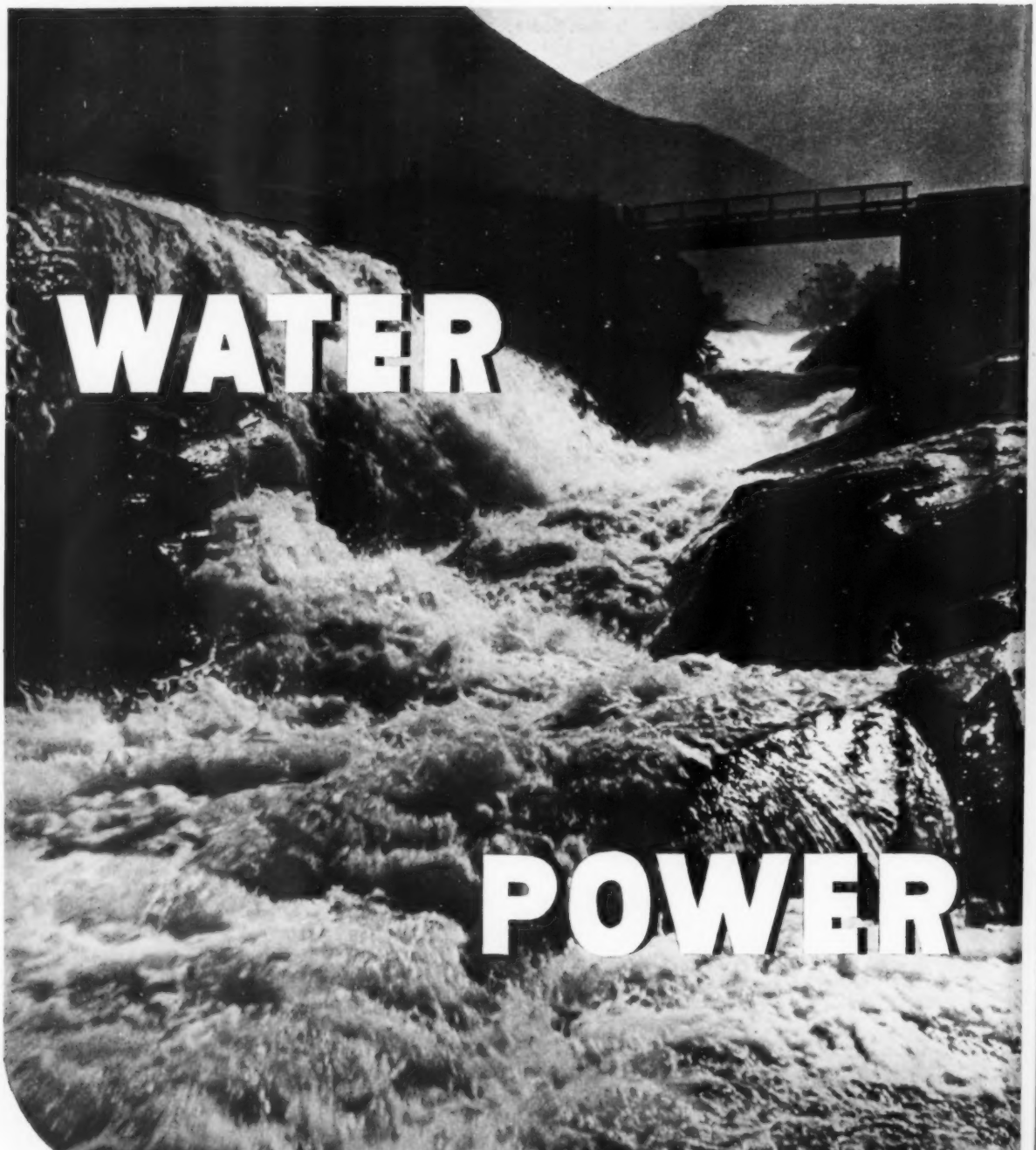

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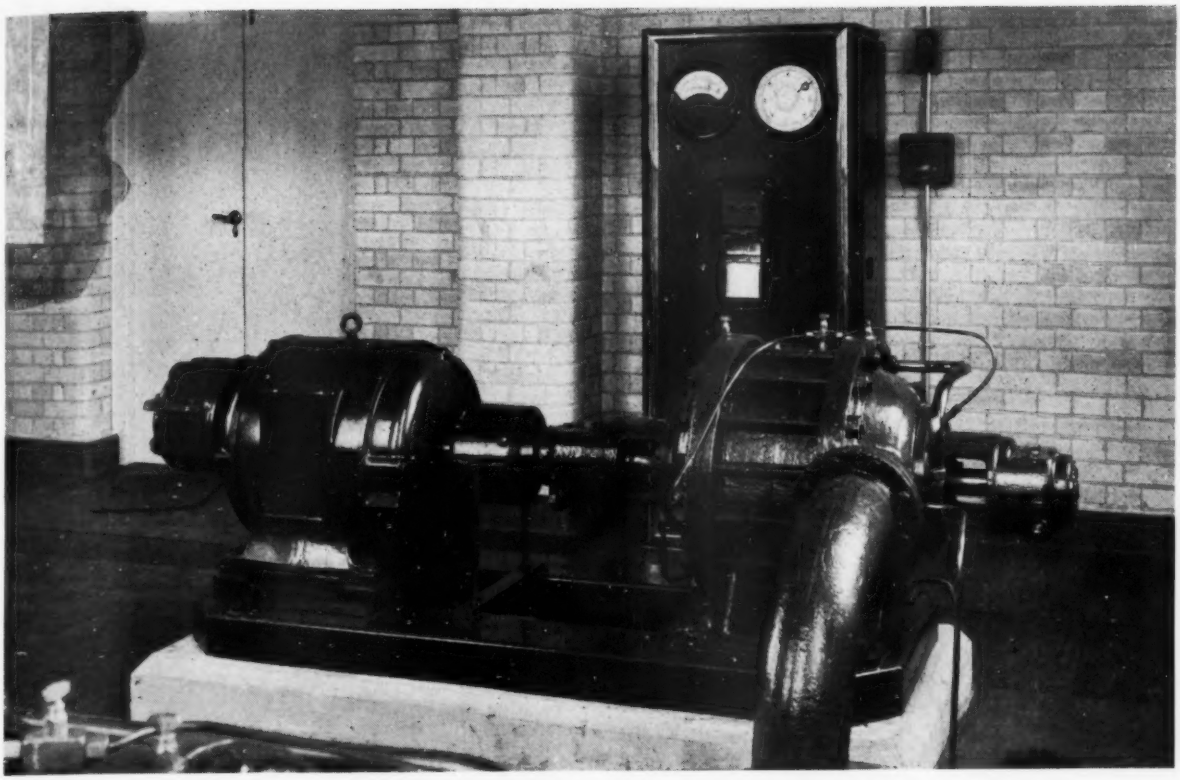

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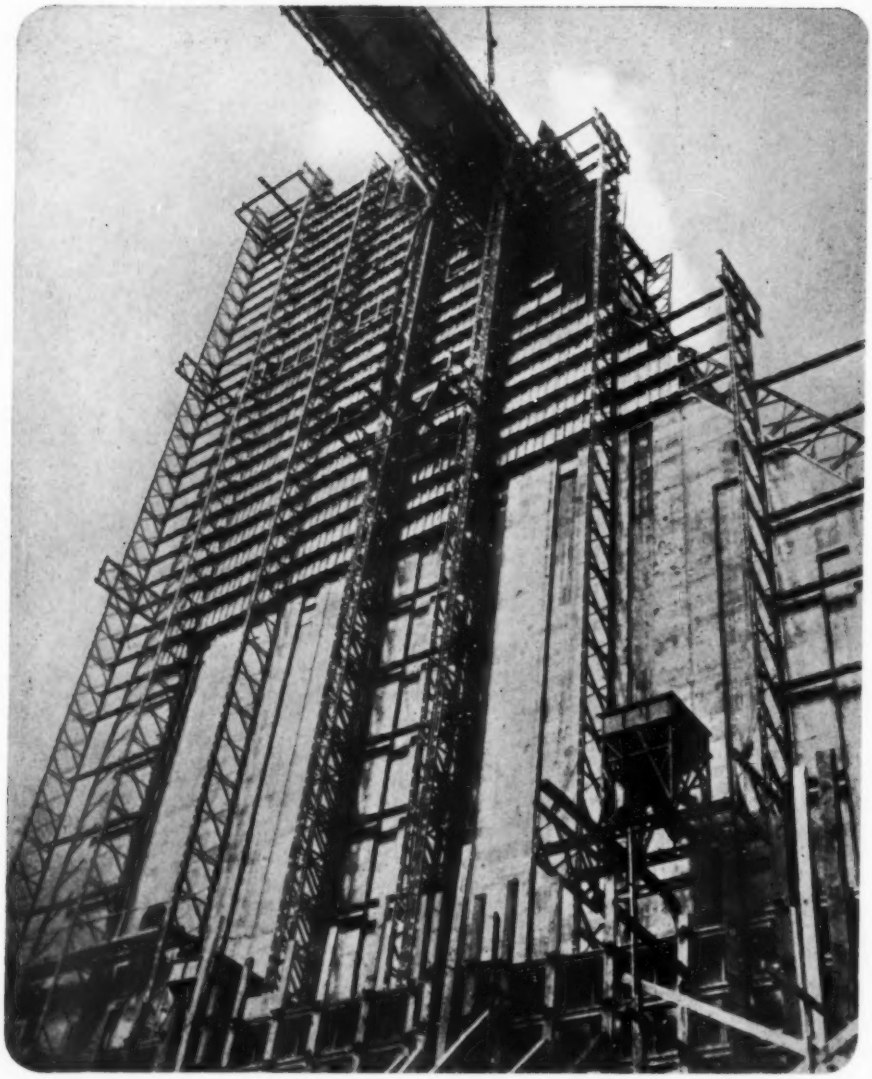

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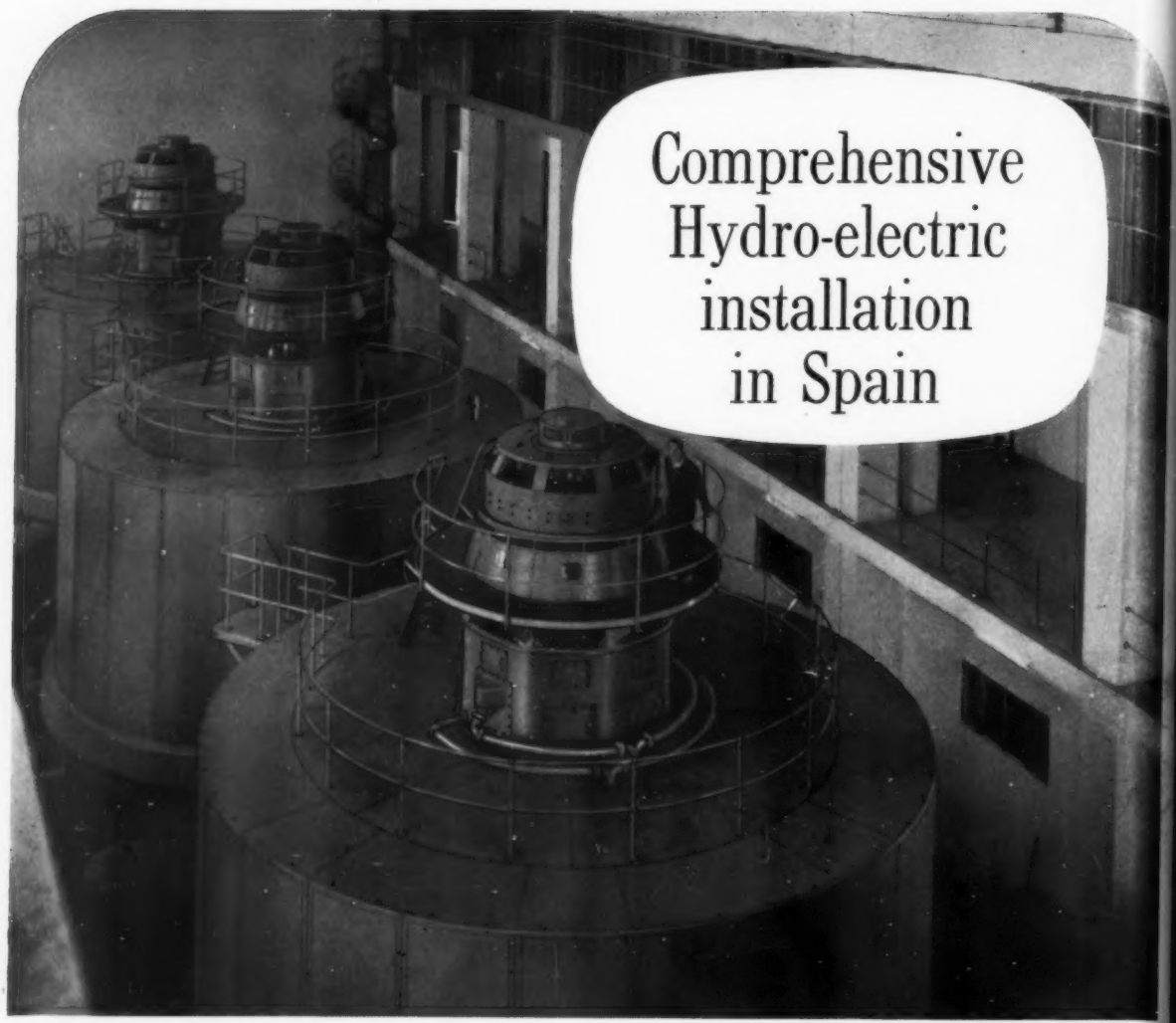
Trasformatori trifasi da 60/60/60/60 MVA
225/125 ± 2 × 5%/6,3/12 kV - 50 Hz
MACCHINE E APPARECCHIATURE PER GENERARE, TRASFORMARE E UTILIZZARE L'ENERGIA ELETTRICA
MACHINES ET APPAREILLAGES POUR ENGENDRER, TRANSFORMER ET UTILISER L'ÉNERGIE ÉLECTRIQUE
MACHINES AND EQUIPMENT FOR GENERATING, TRANSFORMING AND UTILISING ELECTRIC POWER
MASCHINEN UND AUSRÜSTUNGEN ZUR ERZEUGUNG, UNFORMUNG UND AUSNÜTZUNG VON ELEKTRISCHER ENERGIE
ASG
ANSALDO-SAN GIORGIO
GENOVA
GENOVA (ITALIA) - MURA DI SANTA CHIARA, 1 - TELEFONO: 586.741 TELEGRAMMI: SERAS-GENOVA



Comprehensive Hydro-electric installation in Spain

'ENGLISH ELECTRIC' supplied to S.A. Hidroeléctrica Española the complete equipment for their Cofrentes Power Station. The illustration shows the three 46,000 kVA alternators, driven by 56,000 h.p. 300 r.p.m. vertical reaction water turbines which operate from a net head of 136 metres. In addition to the main units, 'ENGLISH ELECTRIC' supplied a 500 kVA auxiliary set.

'ENGLISH ELECTRIC' also supplied the main and auxiliary transformers and all the switchgear, including twelve 150 kV airblast circuit breakers, and were main contractors for the three 450-metre long pipelines and the 175-ton power station crane.

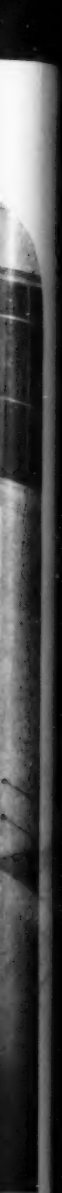
The ENGLISH ELECTRIC Company offer the great advantage of being designers and manufacturers of the complete hydro-electric unit, including governors, valves and all auxiliary equipment. The Cofrentes installation is yet another example of the comprehensive hydro-electric contracts entrusted to 'ENGLISH ELECTRIC'.

'ENGLISH ELECTRIC'

hydro-electric equipment

THE ENGLISH ELECTRIC COMPANY LIMITED, QUEEN'S HOUSE, KINGSWAY, LONDON, W.C.2

Hydro-electric Department, Stafford

WORKS: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL · ACCRINGTON

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